USERS GUIDE

Synapse Network Appliance Protocol SNAP®

Reference Manual for Version 2.1

Wireless Technology to Control and Monitor Anything from Anywhere™

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1. Introduction

SNAP and SNAPpy

The Synapse *SNAP* product line provides an extremely powerful and flexible platform for developing and deploying IEEE 802.15.4 based wireless applications.

SNAP is an acronym for Synapse Network Appliance Protocol, and is the protocol spoken by all Synapse wireless nodes. The term SNAP has also evolved over time to refer generically to the entire product line. For example, we often speak of "SNAP Networks", "SNAP Nodes", and "SNAP Applications".

SNAP core software runs on each SNAP node. This core code handles 802.15.4 radio communications, as well as implementing a mini-Python interpreter.

The subset of Python implemented by the core software is named SNAPpy. Scripts written in SNAPpy (also referred to as "Device Images", "SNAPpy images" or even "Snappy Images") can be uploaded into SNAP Nodes serially (or even over the air), and dramatically alter the node's capabilities and behavior.

Portal and Gateway

Synapse *Portal* is a standalone software application which runs on a standard PC. Using a USB or RS232 interface, it connects to any node in the SNAP Wireless Network, becoming a graphical user interface (GUI) for the entire network. Using Portal, you can quickly and easily create, deploy, configure and monitor SNAP-based network applications. Once connected, the Portal PC has its own unique Network Address, and can participate in the SNAP network as a peer.

Synapse *Gateway* is a standalone server application, which also runs on a standard PC. It connects to SNAP nodes over USB or RS-232 (just like Portal), but instead of providing a GUI, it acts as an XML-RPC server, allowing *your own* client applications to invoke functions on SNAP nodes, even over the Internet. These client applications can be written in Python, C++, C#, etc.

It is also possible for Portal to connect to your SNAP network through the Gateway (instead of a direct USB or RS-232 connection). This allows you to develop, configure, and deploy SNAP applications over the Internet.

Through a Gateway, you can have a total of 15 simultaneous client connects, which can be a mix of Portals and your own custom client applications.

There are several main documents you need to be aware of:

Start with an "Evaluation Kit Users Guide"

Each evaluation kit comes with its own **Users Guide**. For example, the EK2500 kit comes with the **EK2500 Evaluation Kit Users Guide** ("EK2500 Guide"), and the EK2100 kit comes with the **EK2100 Evaluation Kit Users Guide** ("EK2100 Guide").

Each of these guides walks you through the basics of unpacking your evaluation kit, setting up your wireless nodes, and installing Portal software on your PC. You should start with one of those manuals, even if you are not starting with an EK2500 or EK2100 kit (Synapse SNAP nodes and even their component *RF Engines* are also sold separately, as well as bundled into evaluation kits).

About This Manual

This manual assumes you have read and understood either the "EK2100 Guide" or the "EK2500 Guide". It assumes you have installed the Portal software, and are now familiar with the basics of discovering nodes, uploading SNAPpy scripts into them, and controlling and monitoring them from Portal.

This manual covers two broad categories of information:

> The first category is information about *SNAP and SNAPpy*. This category runs from section 2 through section 11, and includes topics like the SNAPpy language, and the built-in functions that are accessible from it. You will also find information about the different node configuration parameters that can be changed.
>
> The second category is information about *Portal*. Sections 12 through 15 pick up where the EK2100 and EK2500 Users Guide left off, and cover the remaining toolbar buttons, pull-down menus, and tabbed panes.

Other Important Documentation

Be sure to check out all of the SNAP documentation:

If you are migrating to SNAP version 2.1 from version 2.0, check out the "**SNAP 2.1 Release Notes"**. This document highlights the changes made since the original 2.0 release.

There is a separate user manual on the new Synapse *Gateway*. The *Gateway* allows you to monitor and control your nodes from remote locations, over TCP/IP.

There is a wealth of valuable information in the "**SNAP Hardware Technical Manual**". This document covers every jumper and every connector of every type of node included in the evaluation kit.

For your convenience, much of the information available in the "Hardware Technical Manual" has been broken down into individual "Quick Start" guides. For example, there is a "**SN171 Proto Board Quick Start**" and a "**SN132 SNAPstick Quick Start**".

There is also a dedicated support forum at http://forums.synapse-wireless.com.

In the forum, you can see questions and answers posted by other users, as well as post your own questions. The forum also has examples and Application Notes, waiting to be downloaded.

2. SNAP Overview

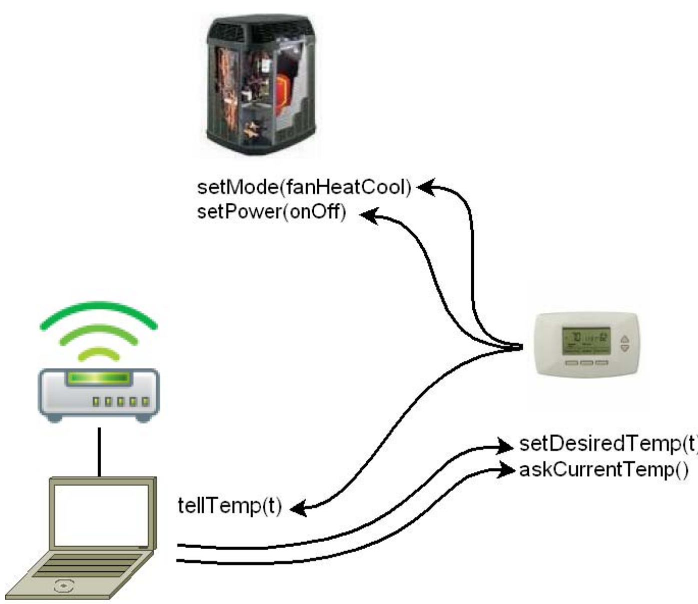
SNAP, the Synapse Network Appliance Protocol, is a networking protocol which uses the IEEE 802.15.4 physical layer for wireless communications. It is also an umbrella term for the Synapse family of software technologies which together form an integrated, end-to-end solution for wireless monitoring and control. The latest version is 2.1, which this document covers.

Key features of SNAP

- All devices are peers – any device can be a bridge for Portal, do mesh routing, sleep, etc. *There are no "coordinators" in SNAP.*
- SNAP implements a full mesh topology. Any node can talk directly to any other node within radio range, and can talk indirectly to any node within the SNAP network.
- Communication among devices can be unicast (reliable) or multicast (unacknowledged)
- Remote Procedure Call (RPC) among peers is the fundamental method of messaging.
- The PC based user interface (Portal) appears as a peer device on the SNAP network.

RPC

All SNAP devices implement a core set of built-in *functions* (procedures) to handle basic network configuration, system services, and device hardware control. These *functions* may be invoked remotely from Portal or from any other device on the SNAP network. Additional *user-defined functions* may be uploaded to devices as well. This upload process can be over directly connected serial interfaces, or over the air. Once uploaded, these functions are also callable locally or remotely, and may themselves invoke local and remote functions. Functions are defined in an embedded subset of the Python language, called SNAPpy.



Example HVAC System Showing RPC Call-flow (arrows)

SNAPpy Scripting

SNAPpy is a subset of the Python programming language, optimized for low-power embedded devices. A SNAPpy “script” is a collection of functions and data which are processed by Portal and uploaded to SNAP devices. All SNAP devices are capable of running SNAPpy – it is the native language of RPC calls.

SNAPpy Examples

On installation, Portal creates a folder under “My Documents” called “Portal\snappyImages”. Several sample script files are installed here by default. These scripts are plain text files, which may be opened and edited with Portal’s built-in editor. External text editors or even full-fledged Python Integrated Development Environments (IDEs) may also be used. Feel free to copy the sample scripts (the installed copies are read-only), and create your own as you build custom network applications.

Portal Scripting

Similar to the SNAP nodes, Portal can also be extended through scripting. By loading a script, you can add new functions to Portal, which you (and the other SNAP nodes) can call.

Python

Instead of SNAPpy, Portal scripts are written in full Python. Python is a very powerful language, which finds use in a wide variety of application areas. Although the core of Python is not a large language, it is well beyond the scope of this document to cover it in any detail.

You won’t have to search long to find an immense amount of information regarding Python on the Web. Besides your favorite search engine, a good place to start looking for further information is Python’s home site:

http://python.org/

The **Documentation** page on Python’s home site contains links to tutorials at various levels of programming experience, from beginner to expert.

As mentioned earlier, Portal acts as a peer in the SNAP network, and can send and receive RPC calls like any other Node. Like other nodes, Portal has a Device Image (script) which defines the functions callable by incoming RPC messages. Since Portal runs on a PC, its script executes in a full Python environment with access to the many libraries, services, and capabilities available there.

> **SNAPpy RPC → Portal : Gateway to Full Python…**
> Thanks to this capability, it is quite simple for a low-power device on the network to (via an RPC call to Portal) send an email or update a database in response to some monitored event.

Portal Script Examples

On installation, Portal creates a folder under “My Documents” called “Portal”. Several sample script files are installed here by default. These scripts are plain text files, which may be opened and edited with Portal’s built-in editor. External text editors or even full-fledged Python Integrated Development Environments (IDEs) may also be used. Feel free to copy the sample scripts (the installed copies are read-only), and create your own as you build custom network applications.

Be sure to make copies of the provided read-only examples.

If you try to be “clever”, and change the existing files to be writable, your changes to these example will be overwritten when you install the next version of Portal.

3. SNAPpy – The Language

SNAPpy is basically a subset of Python. Here is a quick overview of the SNAPpy language.

Statements must end in a newline

```
print “I am a statement”
```

The # character marks the beginning of a comment

```
print “I am a statement with a comment” # this is a comment
```

Indentation is significant

```
print “I am a statement”
   print “I am a statement at a different indentation level” # this is an error
```

Indentation <u>is</u> used after statements that end with a colon (:)

```
if x == 1:
   print “Found number 1”
```

Branching is supported via “if”, “else”, and “elif”

```
if x == 1:
   print “Found number 1”
elif x == 2:
   print “Found number 2”
else:
   print “Did not find 1 or 2”
```

Looping is supported via “while”

```
x = 10
while x > 0:
   print x
   x = x -1
```

Identifiers are case sensitive

```
X = 1
x = 2
```

Here “X” and “x” are two different variables

Identifiers must start with a non-numeric characters

```
x123 = 99 # OK
123x = 99 # not OK
```

Identifiers may only contain alphanumeric characters and underscores

```
x123_percent = 99 # OK
$%^ = 99 # not OK
```

Variables can be Booleans, Integers, or Strings

```
A = True
B = False
C = 123
D = “hello”
```

String Variables can contain Binary Data

```
A = “\x00\xFF\xAA\x55”
```

You define new functions using “def”

```
def sayHello():
   print “hello”

sayHello() # prints the word “hello”
```

Functions can take parameters

```
def adder(a, b):
   print a+b
```

Functions can return values

```
def adder(a, b):
   return a+b

print adder(1, 2) # would print out "3"
```

Functions can do nothing

```
def placeHolder(a,b):
   pass
```

Functions cannot be empty

```
def placeHolder(a,b):
   # ERROR! - you have to at least put a "pass" statement here
```

Variables at the top of your script are global

```
x = 99 # this is a global variable

def sayHello():
   print "hello"
```

Variables within functions are usually local…

```
x = 99 # this is a global variable

def showNumber():
   x = 123 # this is a separate local variable
   print x # prints 123
```

…unless you explicitly say you mean the global one

```
x = 99 # this is a global variable

def showGlobal():
   print x # this shows the current value of global variable x

def changeGlobal():
   global x # because of this statement…
   x = 99 # …this changes the global variable x

def changeLocal():
   x = 42 # this statement does not change the global variable x
   print x # will print 42 but the global variable x can have some other value
```

The usual conditionals are supported

Symbol	Meaning
==	Is equal to
!=	Is not equal to
>	Greater than
<	Less than
>=	Greater than or equal to
<=	Less than or equal to

```
if 2 == 4:
   print “something is wrong!”

if 1 != 1:
   print “something is wrong!”

if 1 < 2:
   print “that’s what I thought”
```

The usual math operators are supported

Symbol	Meaning
+	Addition
-	Subtraction
*	Multiplication
/	Division
%	Modulo (remainder function)

```
y = m*x + b
z = 5 % 4 # z is now 1
result = 8 / 4
```

SNAPpy does not support floating point, only integers.

SNAPpy integers are 16-bit signed values -32768 through 32767.

The usual Boolean functions are supported

Symbol	**Meaning**
and	Both must be True
or	Either can be True
not	Boolean inversion (not True == False)

Result = True and True # Result is True
Result = True and False # Result is False
Result = False and True # Result is False
Result = False and False # Result is False

Result = True or True # Result is True
Result = True or False # Result is True
Result = False or True # Result is True
Result = False or False # Result is False

Variables do have types, but they can change on the fly

x = 99 # variable x is currently an integer (int)
x = “hello” # variable x is now a string (str)
x = True # variable x is now a Boolean (bool)

4. SNAPpy versus Python

Here are more details about SNAPpy, with emphasis on the differences between SNAPpy and Python.

Modules

SNAPpy supports import of user-defined as well as standard predefined Python source library modules.

from *module* import * # Supported
import module # Not supported

Variables

Local and Global variables are supported. On RAM constrained devices, SNAPpy images are limited to 64 system globals and 64 concurrent locals.

Functions

Up to 255 "public" functions may be defined. These are remotely callable using SNAP RPC protocol.

Non-public functions (prefixed with underscore) are limited only by the size of flash memory.

Data Types

SNAPpy supports the following fundamental Python data types:

NoneType, int, bool, string, function

int is a signed 16-bit integer, -32768 through 32767

string has max size of 255 bytes (*note*: built-in slice/concat/rpc have smaller limits)

SNAPpy does *not* currently support the following common Python types:

float, long, complex, tuple, list, dict, set
User-defined objects (*class* types)

Keywords

The following Python reserved identifiers are supported in SNAPpy:

and from not while elif global or else if pass break import print continue return def is

The following identifiers are reserved, but not yet supported in SNAPpy:

del as with assert yield except class exec in raise finally for lambda try

Operators

SNAPpy supports all Python operators, with the exception of *floor (//)* and *power (**)*.

+ - * / %

<< >> & | ^ ~

< > <= >= == != <>

Slicing

Slicing is supported for **string** data types. The current version of SNAPpy is constrained to a single dynamic "slice buffer," which is 64 bytes in size. Subsequent slices will overwrite this buffer.

Concatenation

Concatenation is supported for **string** data types. The current version of SNAPpy is constrained to a single dynamic "concatenation buffer," which is 64 bytes in size. Subsequent concatenation will overwrite this buffer.

Subscripting

Subscripting is supported for **string** data types.

Expressions

SNAPpy supports all Python Boolean, Binary bit-wise, Shifting, arithmetic, and comparison expressions – including the ternary **if** form.

Builtins

Supported Python built-ins: **len, ord, chr, int, str**
Additionally, many RF module-specific embedded network and control built-ins are supported.

Print

SNAPpy also supports a print statement. Normally each line of printed output appears on a separate line. If you do not want to automatically advance to the next line (if you do not want an automatic Carriage Return and Line Feed), end your print statement with a comma (“,”) character.

```
print “line 1”
print “line 2”
print “line 3 ”,
print “and more of line 3”
```

5. SNAPpy Application Development

This section outlines some of the basic issues to be considered when developing SNAP based applications.

Event Driven Programming

Applications in SNAP often have several activities going on concurrently. How is this possible, with only one CPU on the RF Engine? In SNAP, concurrency is achieved through event-driven programming. This means that all SNAPpy functions run quickly to completion, and <u>never</u> "block" or "loop" waiting for something. External *events* will trigger SNAPpy functions.

SNAP Hooks

There are a number of events in the system which we might like to trigger some SNAPpy function "handler". When defining your SNAPpy scripts, there is a way to associate functions with these external events. That is done by specifying a "HOOK" identifier for the function. The following HOOKs are defined:

•**HOOK_STARTUP**
–Called on device bootup
•**HOOK_GPIN**
–Called on monitored hardware pin transition
•**HOOK_100MS**
–Called every 100ms
•**HOOK_STDIN**
–Called when "user input" data is received
•**HOOK_STDOUT**
–Called when "user output" data is sent
•**HOOK_RPC_SENT**
–Called when outgoing RPC call is sent

Within a SNAPpy script, the method for specifying a HOOK is as follows:
snappyGen.setHook(SnapConstants.HOOK_XXX, eventHandlerXXX)

Transparent Data (Wireless Serial Port)

SNAP supports efficient, reliable bridging of serial data across a wireless mesh. Data connections using the transparent mode can exist alongside RPC based messaging.

Scripted Serial I/O (SNAPpy STDIO)

SNAP's transparent mode takes data from one interface and forwards it to another interface (possibly the radio), but the data is not altered in any way (or even examined).

SNAPpy scripts can *also* interact directly with the serial ports, allowing custom serial protocols to be implemented. For example, one of the included sample scripts shows how to interface serially to an external GPS unit.

The Switchboard

The flow of data through a SNAP device is configured via the Switchboard. This allows connections to be established between sources and sinks of data in the device. The following Data Sources/Sinks are defined in the file switchboard.py, which can be imported by other SNAPpy scripts:

DS_NULL
DS_UART1
DS_UART2
DS_TRANSPARENT
DS_STDIO
DS_PACKET_SERIAL

The SNAPpy API for creating Switchboard connections is:

crossConnect(*dataSrc1*, *dataSrc2*)	Cross-connect SNAP data-sources
uniConnect(*dst*, *src*)	Connect src->dst SNAP data-sources

For example, to configure UART1 for Transparent (Wireless Serial) mode, put the following statement in your SNAPpy startup handler:

```
crossConnect(DS_UART1, DS_TRANSPARENT)
```

The following table is a matrix of possible Switchboard connections. Each cell label describes the "mode" enabled by row-column cross-connect.

	UART0	**UART1**	**Transparent**	**Stdio**	**PacketSerial**
UART0	Loopback	Crossover	Wireless Serial	Local Terminal	Local Gateway
UART1		Loopback	Wireless Serial	Local Terminal	Local Gateway
Transparent			Loopback	Remote Terminal	Remote Gateway

Refer to the API documentation on crossConnect() in section 7 for more details.

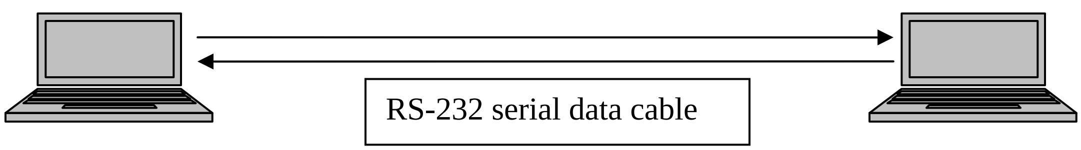
Debugging

Application development with SNAP offers an unprecedented level of interactivity in embedded programming. Using Portal you can quickly upload bits of code, test, adjust, and try again. Some tips and techniques for debugging:

1. Make use of the “print” statement to verify control flow and values (be sure to connect STDIO to a UART or *Intercept STDOUT* with Portal)
2. When using Portal’s Intercept feature, you’ll get source line-number information, and symbolic error-codes.
3. Invoke “unit-test” script functions by executing them directly from the *Snappy Modules Tree* in Portal’s **Node Info** panel.

Sample Application – Wireless UART

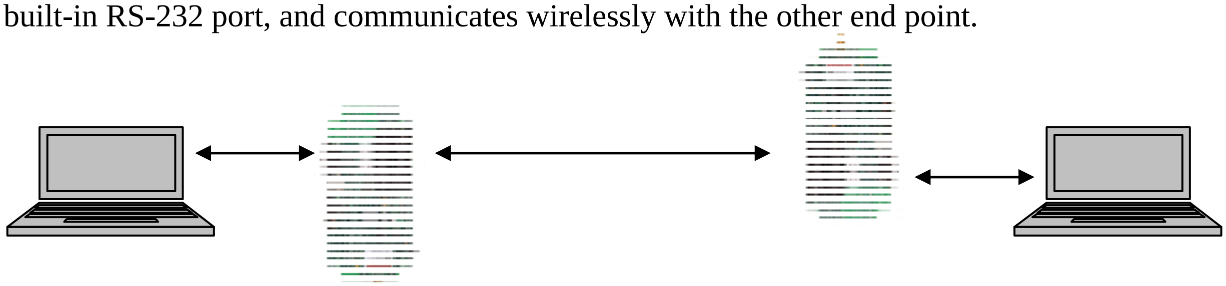
The following scenario is very common: two devices communicating over a RS-232 serial link.



The two devices might be two computers, or perhaps a computer and a slave peripheral. For the remainder of this section, we will refer to these devices as “end points”.

In some cases, a direct physical connection between the two end points is either inconvenient (long distance) or even impossible (mobile end points).

You can use two SNAP nodes to wirelessly emulate the original hardwired connection. One SNAP node gets paired with each end point. Each SNAP node communicates with its local end point using its built-in RS-232 port, and communicates wirelessly with the other end point.



RS-232 **802.15.4 Wireless** **RS-232**

To summarize the requirements of this application:
- We want to go from RS-232, to wireless, back to RS-232
- We want to implement a point-to-point bidirectional link
- We don’t want to make any changes to the original endpoints (other than cabling)

This is clearly a good fit for the **Transparent Mode** feature of SNAPpy, but there are still choices to be made around "how will the nodes know *who* to talk to?"

Option 1 – Two Scripts, Hardcoded Addressing

A script named dataMode.py is included in the set of example scripts that ships with Portal. Because it is one of the demo scripts, it is write-protected. Using Portal's "Save As" feature, create two copies of this script (for example, dataModeA.py and dataModeB.py). You can then edit each script to specify the *other* nodes address, before you upload both scripts into their respective nodes.

The full text of dataMode.py is shown below. Notice this script is only 19 lines long, and 8 of those lines are comments (and 3 are just whitespace).

```
"""
Example of using two SNAP wireless nodes to replace a RS-232 cable
Edit this script to specify the OTHER node's address, and load it into a node
Node addresses are the last three bytes of the MAC address
MAC Addresses can be read off of the RF Engine sticker
For example, a node with MAC Address 001C2C1E 86001B67 is address 001B67
In SNAPpy format this would be address "\x00\x1B\x67"
"""
from switchboard import *

otherNodeAddr = "\x4B\x42\x35" # <= put the address of the OTHER node here

def startupEvent():
    initUart(1, 9600) # <= put your desired baudrate here!
    flowControl(1, False) # <= set flow control to True or False as needed
    crossConnect(DS_UART1, DS_TRANSPARENT)
    ucastSerial(otherNodeAddr)

snappyGen.setHook(SnapConstants.HOOK_STARTUP, startupEvent)
```

The script as shipped defaults to 9600 baud, no hardware flow control. Edit these settings as needed, too.

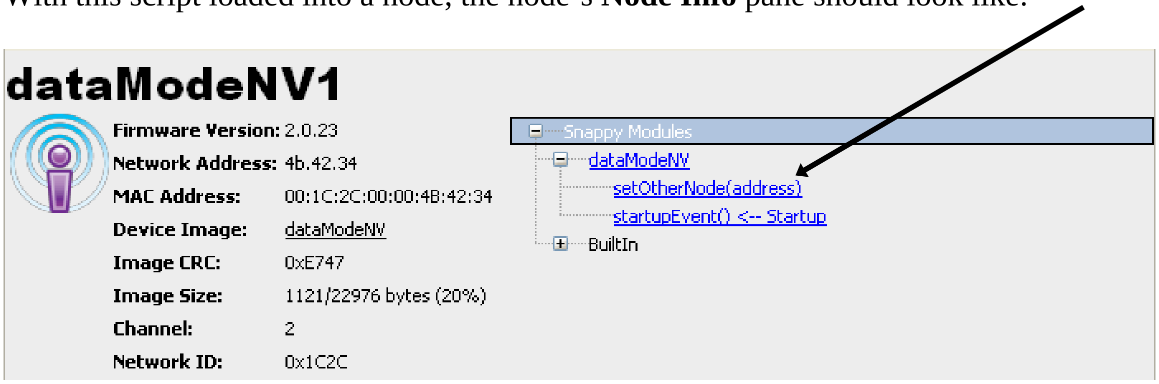
With these two edited scripts loaded into the correct nodes (remember, you are telling each node who the *other* node is, each node already knows its own addresses), you have just created a wireless serial link.

Option 2 – One Script, Manually Configurable Addressing

Instead of hard-coding the "other node" address within each script, you could have both nodes share a common script, and use SNAPpy's **Non-Volatile Parameter (NV Param** for short**)** support to specify the addressing, *after* the script was loaded into the unit.

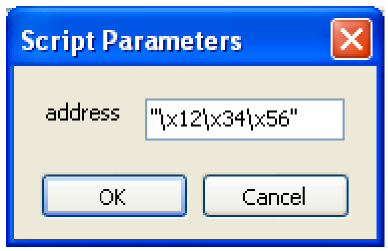
Look in your snappyImages directory for a script named dataModeNV.py. Since we won't be making any changes to this script, there is no need to make a copy of it. Simply load it into both nodes as-is.

With this script loaded into a node, the node's **Node Info** pane should look like:



Click on setOtherNode(address) in the Snappy Modules tree, and when prompted by Portal, enter the address of the *other* node **as a quoted string** (standard Python "binary hex" format).

For example, if the other node is at address 12.34.56, in the Portal dialog box you would enter "\x12\x34\x56".



Do this for both nodes.

Here is the source code to SNAPpy script dataModeNV.py

```
"""
Example of using two SNAP wireless nodes to replace a RS-232 cable
After loading this script into a SNAP node, invoke the setOtherNode(address)
function (contained within this script) so that each node gets told "who his
counterpart node is". You only have to do this once (the value will be preserved
across power outages and reboots) but you DO have to tell BOTH nodes who their
counterparts are!

The otherNodeAddr value will be saved as NV Parameter 254, change this if needed.
Legal ID numbers for USER NV Params range from 128-254.

Node addresses are the last three bytes of the MAC address
MAC Addresses can be read off of the RF Engine sticker
For example, a node with MAC Address 001C2C1E 86001B67 is address 001B67
In SNAPpy format this would be address "\x00\x1B\x67"
"""
from switchboard import *

OTHER_NODE_ADDR_ID = 254

def startupEvent():
    """System startup code, invoked automatically (do not call this manually)"""
    global otherNodeAddr
    initUart(1, 9600) # <= put your desired baudrate here!
    flowControl(1, False) # <= set flow control to True or False as needed
    crossConnect(DS_UART1, DS_TRANSPARENT)
    otherNodeAddr = loadNvParam(OTHER_NODE_ADDR_ID)
    ucastSerial(otherNodeAddr)

def setOtherNode(address):
```

```
    """Call this at least once, and specify the OTHER node's address"""
    global otherNodeAddr
    otherNodeAddr = address
    saveNvParam(OTHER_NODE_ADDR_ID, otherNodeAddr)
    ucastSerial(otherNodeAddr)

snappyGen.setHook(SnapConstants.HOOK_STARTUP, startupEvent)
```

This script shows how to use the saveNvParam() and loadNvParam() functions to have units remember important configuration settings. The script could be further enhanced to treat the baud rate and hardware handshaking options as User NV Parameters as well.

You can read more about NV Parameters in section 7 and section 9.

6. Advanced SNAPpy Application Development

This section describes how to use some of the more advanced features of SNAP 2.1. Topics covered include:

Interfacing to external CBUS slave devices (emulating a CBUS master)
Interfacing to external SPI slave devices (emulating a SPI master)
Interfacing to external I2C slave devices (emulating a I2C master)

Interfacing to external CBUS slave devices

CBUS is a clocked serial bus, similar to SPI. It requires at least four pins:

CLK – master timing reference for all CBUS transfers
CDATA – data from the CBUS master to the CBUS slave
RDATA – data from the CBUS slave to the CBUS master
CS – At least one Chip Select (CS)

Using the existing readPin() and writePin() functions, virtually *any* type of device can be interacted with via a SNAPpy script, including external CBUS slaves. Arbitrarily chosen GPIO pins could be configured as inputs or outputs by using the setPinDir() function. The CLK, CDATA, and CS pins would be controlled using the writePin() function. The RDATA pin would be read using the readPin() function.

The problem with a strictly SNAPpy based approach is speed – CBUS devices tend to be things like voice chips, with strict timing requirements. Being an interpreted language, it is hard for SNAPpy to keep up.

To solve this problem, dedicated CBUS support (**master emulation only**) has been added to the set of SNAPpy built-in functions. Two functions (callable from SNAPpy but implemented in optimized C code) support reading and writing CBUS data:

cbusRd(*numToRead*) – "shifts in" the specified number of bytes
cbusWr(*str*) – "shifts out" the bytes specified by *str*

To allow the cbusRd() and cbusWr() functions to be as fast as possible, the GPIO pins used for CBUS CLK, CDATA, and RDATA are fixed:

GPIO 12 is always used as the CBUS CDATA pin
GPIO 13 is always used as the CBUS CLK pin
GPIO 14 is always used as the CBUS RDATA pin

Note! – These pins are only dedicated if you are actually using the CBUS functions. If not, they remain available for other functions.

You will also need as many Chip Select pins as you have external CBUS devices. You can choose any available GPIO pin(s) to be your CBUS chip selects. The basic program flow becomes:

```
# select the desired CBUS device
writePin(somePin, False) # assuming the chip select is active-low
# read bytes from the selected CBUS device
cbusRd(10) # <- you specify how many bytes to read
# deselect the CBUS device
writePin(somePin, True) # assuming the chip select is active-low
```

CBUS writes are handled in a similar fashion.

If you are already familiar with CBUS devices, you should have no trouble using these functions to interface to external CBUS chips.

A detailed example of interfacing to an external CBUS voice chip will be the topic of an upcoming application note.

Interfacing to external SPI slave devices

SPI is another clocked serial bus. It typically requires at least four pins:

CLK – master timing reference for all SPI transfers
MOSI – Master Out Slave In – data line FROM the master TO the slave devices
MISO – Master In Slave Out – data line FROM the slaves TO the master
CS – At least one Chip Select (CS)

SPI also exists in a three wire variant, with the MOSI pin serving double-duty.

Numerous options complicate use of SPI:

Clock Polarity – the clock signal may or may not need to be inverted
Clock Phase – the edge of the clock actually used varies between SPI devices
Data Order – some devices expect/require Most Significant Bit (MSB) first, others only work Least Significant Bit (LSB) first
Data Width – some SPI devices are 8-bit, some are 12, some are 16.

The SPI support routines in SNAPpy can deal with all these variations, but you will have to make sure the options you specify in your SNAPpy scripts match the settings required by your external devices.

Like what was done for CBUS devices, dedicated SPI support (**master emulation only**) has been added to the set of SNAPpy built-in functions. Four functions (callable from SNAPpy but implemented in optimized C code) support reading and writing SPI data:

In order to support both three wire and four wire SPI, there are more spiXXX() functions than you might first expect.

spiInit(*cpol*, *cpha*, *isMsbFirst*, *isFourWire*) - setup for SPI (many options!)
spiWrite(*byteStr*, *bitsInLastByte*=8) - send data out SPI
spiRead(*byteCount*, *bitsInLastByte*=8) - receive data in from SPI (3 wire only)
spiXfer(*byteStr, bitsInLastByte*=8) - bidirectional SPI transfer (4 wire only)

Four-wire SPI interfaces transfer data in both directions simultaneously, and should use the spiXfer() function.

Some SPI devices are write-only, and you can use spiWrite() to send data to them (three-wire or four-wire hookup).

Some three wire devices are read-only, and you must use function spiRead().

The data width for SPI devices is not standardized. Devices that use a data width that is a multiple of 8 are trivial (send 2 bytes to make 16 bits total for example). However, device widths such as 12 bits are common. To support these "non-multiples-of-8", you can specify how much of the last byte to actually send or receive. For example,

spiWrite("\x12\x34", 4)

…will send a total of 12 bits: all of the first byte (0x12), and the first (or last) nibble of the second byte.

> *Which* 4 bits out of the total 8 get sent are a function of the "send LSB first" setting, which is specified as part of the spiInit() call.

To allow these functions to be as fast as possible, the GPIO pins used for CLK, MOSI, and MISO are fixed:

GPIO 12 is always used as the MOSI pin
GPIO 13 is always used as the CLK pin
GPIO 14 is always used as the MISO pin, unless running in three wire mode

(The chip select pin is what raises the total number of pins to 3 or 4)

Note! – These pins are only dedicated if you are actually using the SPI functions. If not, they remain available for other functions. Also, if using three wire SPI, GPIO 14 remains available.

You will also need as many Chip Select pins as you have external SPI devices. You can choose any available GPIO pin(s) to be your SPI chip selects. The basic program flow becomes:

```
# select the desired SPI device
writePin(somePin, False) # assuming the chip select is active-low
# Transfer data to the selected SPI device
spiWrite("\x12\x34\x56")
# deselect the SPI device
writePin(somePin, True) # assuming the chip select is active-low
```

SPI reads are handled in a similar fashion.

The specifics of *which* bytes to send to a given SPI slave device (and what the response will look like) depend on the SPI device itself. You will have to refer to the manufacturer's data sheet for any given device you wish to interface to.

For examples of using the new SNAPpy SPI functions to interface to external devices, look at the following scripts that are bundled with Portal:

spiTests.py – This is the overall SPI demo script
LTC2412.py – Example of interfacing to a 24-bit Analog To Digital convertor

Script spiTests.py imports the other script, and exercises some of the functions within it.

Interfacing to external I2C slave devices

Technically the correct name for this two-wire serial bus is Inter-IC bus or I^2C.
Information on this popular two-wire hardware interface is readily available on the web, http://www.i2c-bus.org/ is one starting point you could use. In particular look for a document called "The I^2C-bus and how to use it (including specifications)".

I2C uses two pins:

SCL – Serial Clock Line
SDA – Serial Data line (bidirectional)

Because both the value and direction (input versus output) of the SCL and SDA pins must be rapidly and precisely controlled, dedicated I2C support functions have been added for SNAP version 2.1.

i2cInit(*enablePullups*) – Prepare for I2C operations (call this to setup for I2C)
i2cWrite(*byteStr*, *retries*, *ignoreFirstAck*) – Send data over I2C to another device
i2cRead(*byteStr*, *numToRead*, *retries*, *ignoreFirstAck*) – Read data from device
getI2cResult() – used to check the result of the other functions

These routines are covered in more detail in section 7 of this document.

By using these routines, your SNAPpy script can operate as an I2C **bus master**, and can interact with I2C slave devices.

When performing I2C interactions, the following GPIO pins are used:

GPIO 17 is always used as the I2C SDA (data) line
GPIO 18 is always used as the I2C SCL (clock) line

Note! – These pins are only dedicated if you are actually using the I2C functions. If not, they remain available for other functions.

Unlike CBUS and SPI, I2C does not use separate "chip select" lines. The initial data bytes of each I2C transaction specify an "I2C address". Only the addressed device will respond. So, no additional GPIO pins are needed.

The specifics of *which* bytes to send to a given I2C slave device (and what the response will look like) depend on the I2C device itself. You will have to refer to the manufacturer's data sheet for any given device you wish to interface to.

For examples of using the new SNAPpy I2C functions to interface to external devices, look at the following scripts that are bundled with Portal:

i2cTests.py – This is the overall I2C demo script
M41T81.py – Example of interfacing to a clock/calendar chip
CAT24C128.py – Example of interfacing to an external EEPROM

Script i2cTests.py imports the other two scripts, and exercises some of the functions within them.

7. SNAPpy – The API

This section details the "built-in" functions available to all SNAPpy scripts, as well as through RPC messaging. As of version 2.1, there are over 60 of these functions implemented by the SNAP "core" firmware.

These functions will first be presented in detail alphabetically. They will then be summarized, by category.

Alphabetical SNAP API

bist() – for Synapse internal use only

This function is for Synapse developer use only, and will likely be removed in a future release. User scripts should not bother calling this function.

call() – for Synapse internal use only

This function is for Synapse developer use only, and will likely be removed in a future release. User scripts should not be calling this function.

callback(*callback*, *remoteFunction*, *remoteFunctionArgs…*)

Using the built-in function rpc() it is easy to invoke functions on another node. However, to get data back from that node, you either need to put a script in that node, or use the new callback() function.

Parameter *callback* specifies what function to invoke *with the answer of the remote function*. For example, imagine having a function like the following in SNAP Node "A".

```
def showResult(obj):
   print str(obj)
```

Invoking callback('showResult', …) will cause function showResult() will get called with the live data from the remote node.

Parameter *remoteFunction* specifies what function to invoke on the remote node, for example "readAdc".

If the remote function takes any parameters, then the *remoteFunctionArgs* parameter of the callback() function is where you put them.

For example, node “A” could invoke the following on node “B”:

callback(‘showResult’,’readAdc’,0)

Node “B” would invoke readAdc(0), and then remotely invoke showResult(*the-actual-ADC-reading-goes-here*) on node “A”.

The callback() function is most commonly used with the rpc() function. For example:

rpc(nodeB, ’callback’, ’showResult’, ’readAdc’ ,0)

cbusRd(*numToRead*) – Read bytes in from the CBUS

This function returns a string of bytes read in from the currently selected CBUS device. Parameter *numToRead* specifies how many bytes to read.

For more details on interfacing SNAP Nodes to external CBUS slave devices, refer to section 6.

cbusWr(*str*) – Write bytes out to the CBUS

This function writes the string of bytes specified by parameter *str* out to the currently selected CBUS slave device.

This function does not return anything.

For more details on interfacing SNAP Nodes to external CBUS slave devices, refer to section 6.

chr(*number*) – generates a single-character-string

This function was added for compatibility with Python, and returns a short string based on the number given. For example, chr(0x41) returns the string ‘A’.

crossConnect(*endpoint1*, *endpoint2*) – tie two endpoints together

The SNAPpy switchboard is covered in section 5. Refer to included script “switchboard.py" to see the possible values for *endpoint1* and *endpoint2*.

See also function uniConnect() if what you really want is a one-sided data path.

This function does not return a value.

eraseImage() – Erase any SNAPpy image from the node

This function is used by Portal and Gateway as part of the script upload process, and would not normally be used by user scripts. If you do call this function, be sure to call the resetVm() function first (otherwise the SNAPpy VM will still be *running* the script, as you erase it out from under it).

This function takes no parameters, and does not return a value.

errno() – read and reset latest error code

This function reads the most recent error code from the SNAPpy Virtual Machine (VM), clearing it out as it does so. The possible error codes are:

NO_ERROR = 0
OP_NOT_DEFINED = 1
UNSUPPORTED_OPCODE = 2
UNRESOLVED_DEPENDENCY = 3
INCOMPATIBLE_TYPES = 4
TARGET_NOT_CALLABLE = 5
UNBOUND_LOCAL = 6
BAD_GLOBAL_INDEX = 7
EXCEEDED_MAX_BLOCK_STACK = 8
EXCEEDED_MAX_FRAME_STACK = 9
EXCEEDED_MAX_OBJ_STACK = 10
INVALID_FUNC_ARGS = 11
UNSUBSCRIPTABLE_OBJECT = 12
INVALID_SUBSCRIPT = 13
EXCEEDED_MAX_LOCAL_STACK = 14
BAD_CONST_INDEX = 15

Some of these error codes are unlikely to occur from user generated scripts, but a few would point directly to programming errors in the user's SNAPpy source code. For example:

INCOMPATIBLE_TYPES: Are you trying to add a number to a string?
TARGET_NOT_CALLABLE: Are you trying to invoke foo(), but foo = 123?
UNBOUND_LOCAL: Are you trying to *use* a variable before you put something in it?
INVALID_FUNC_ARGS: Are you passing the wrong *type* of parameters to a function?
Are you passing the wrong *quantity* of parameters?
INVALID_SUBSCRIPT: Are you trying to access str[3] when str = "123"?
EXCEEDED_MAX_LOCAL_STACK: Do you have too many local variables?

flowControl(*uart, isEnabled*) – Enable/disable flow control

The flowControl() function allows you to disable or enable hardware handshaking (flow control).

When flow control is enabled for UART0, GPIO pins 5 and 6 become CTS and RTS pins for that UART. When flow control is enabled for UART1, GPIO pins 9 and 10 become CTS and RTS pins for that UART.

It is important to realize that UART handshake lines are active-low. A low voltage level on the CTS pin is a boolean “False”, but actually means that it *is*” Clear To Send”. A high voltage level on the CTS pins is a boolean “True”, but actually means it is not “Clear To Send”. RTS behaves similarly.

When flow control is ON (*isEnabled* = True), the RF Engine controls the CTS pin to indicate if it can accept more data. The CTS pin is low if the RFE can accept more characters. The CTS pin goes high (temporarily) if the RFE is “full” and cannot accept any more characters (you can keep sending characters, but they will likely be dropped).

When flow control is ON, the RFE *also* **monitors** the RTS pin from the attached serial device. As long as the RFE sees the RTS pin low, the RFE will continue sending characters to the attached serial device (assuming it has any characters to send). If the RFE sees the RTS pin go high, then it will stop sending characters to the attached serial device.

When flow control is OFF (*isEnabled* = False), the RTS and CTS pins are ignored.

The benefit of turning flow control off is that it frees up two more pins (per UART) for use as other I/O. The drawback of turning off flow control is that characters can be dropped.

This function returns no value.

getChannel() – Get which channel the node is on

The getChannel() function returns a number 0-15 representing which SNAP channel the node is currently on.

SNAP channel 0 corresponds to 802.15.4 channel 11, 1 to 12, and so on.

SNAP Channel	**802.15.4 Channel**	**SNAP Channel**	**802.15.4 Channel**	**SNAP Channel**	**802.15.4 Channel**	**SNAP Channel**	**802.15.4 Channel**
0	11	4	15	8	19	12	23
1	12	5	16	9	20	13	24
2	13	6	17	10	21	14	25
3	14	7	18	11	22	15	26

This function takes no parameters.

getEnergy() – Get energy reading from current channel

The getEnergy() function returns the result of a brief 802.15.4 Energy Detection scan.

The result is in the same units as the getLq() function.

This function takes no parameters.

getI2cResult() – Get status code from most recent I2C operation

This function takes no parameters. It returns the result of the most recently attempted I2C operation. The possible return values and their meanings are:

0 = I2C_OFF means I2C was never initialized (you need to call i2cInit()!)
1 = I2C_SUCCESS means the most recent I2C read/write/etc. succeeded
2 = I2C_BUS_BUSY means the I2C bus was in use by some other device
3 = I2C_BUS_LOST means some other device stole the I2C bus
4 = I2C_BUS_STUCK means there is some sort of hardware or configuration problem
5 = I2C_NO_ACK means the slave device did not respond properly

For more information on interfacing SNAP nodes to I2C devices, refer to section 6.

getInfo(*whichInfo*) – Get specified system info

This function has been added in case a script needs to know details about the environment it is running under.

Parameter *whichInfo* specifies the type of information to be retrieved:

0 = Vendor
1 = Radio
2 = CPU
3 = Platform
4 = Build
5 = Version (Major)
6 = Version (Minor)
7 = Version (Build)
8 = Encryption

Based on the value of *whichInfo*, a numeric value is returned. Many of the following “result codes” will be expanding in the future. Here are the currently known values:

Possible result codes for getInfo(Vendor):

0 = Synapse
(to be continued…)

Possible result codes for getInfo(Radio):

0 = 802.15.4
(other radios will be supported in the future)

Possible result codes for getInfo(CPU):

0 = Freescale MC9S08GT60A
(other CPUs will be supported in the future)

Possible result codes for getInfo(Platform):

0 = Synapse RF Engine

Possible result codes for getInfo(Build):

0 = “debug” build (more error checking, slower speed, less SNAPpy room)
1 = “release” build (less error checking, faster speed, more SNAPpy room)

By using getInfo(Major), getInfo(Minor), and getInfo(Build) you can retrieve all three digits of the firmware version number.

Possible result codes for getInfo(Encryption):

0 = None (no encryption support)
1 = AES-128

getLq() – Get the most recent Link Quality

The getLq() function returns a number 0-127 (theoretical) representing the link quality (received signal strength) of the most recently received packet, regardless of which node that packet came from (could be a near node, could be a far node).

Because this value represents – (negative) dBm, lower values represent stronger signals, and higher values represent weaker signals.

This function takes no parameters.

getMs() – Get elapsed milliseconds since startup

The getMs() function returns the value of a free-running timer within the RF Engine. The value returned is in units of milliseconds. The timer is only 16 bits, and rolls back around to 0 every 65.535 seconds.

Because all SNAPpy integers are signed, the counter's full cycle is:

0, 1, 2,…,32766, 32767, -32768, -32767, -32766, …, -3, -2, -1, 0, 1,…

Some scripts use this function to measure elapsed (relative) times.

The value for this function is only updated *between* script invocations. If you do two back-to-back getMs() calls, you will get the same value.

This function takes no parameters.

getNetId() – Get the node's Network ID

The getNetId() function returns the 16-bit Network Identifier (ID) value the node is currently using. The node will only accept packets containing this ID, or a special "wildcard" value of 0xffff (the "wildcard" Network ID is used during the "find nodes" process).

This function takes no parameters.

getStat() – for Synapse internal use only

This function is for Synapse developer use only, and may be changed or removed in a future release. User scripts should not bother calling this function.

imageName() – return name of currently loaded SNAPpy image

Prior to download into a SNAP node, the text form of a SNAPpy script gets compiled into a byte-code image. It is this executable image that gets downloaded into the node, not the original (textual) source code.

The generated image takes its base name from the underlying source script. For example, image "foo.spy" would be generated from a script named "foo.py".

Function imageName() returns the "base name" from the currently loaded image (if there is one). In the example given here, function imageName() would return the string "foo".
This function takes no parameters.

i2cInit(*enablePullups*) – Setup for I2C

This function performs the necessary setup to allow subsequent i2cRead() and i2cWrite() calls to be made.

Parameter *enablePullups* allows <u>internal</u> pullup resistors to be activated for the I2C clock and data lines. These lines do require pull-ups, but normally those pull-ups are part of your external hardware, and parameter *enablePullups* should be False. (Don't "double pullup" the I2C bus).

Setting parameter *enablePullups* to True can come in handy when you don't have a real I2C bus, but are doing quick prototyping by dangling I2C devices directly off the RF Engine.

For more information about interfacing SNAP nodes to I2C devices, refer to section 6.

i2cRead(*byteStr, numToRead, retries, ignoreFirstAck*) – I2C Read

This function can only be used after function i2cInit() has been called.

I2C devices must be addressed before data can be read out of them, so this function really does a write followed by a read.

Parameter *byteStr* specifies whatever "addressing" bytes must be sent to the device to get it to respond.

Parameter *numToRead* specifies how much data to read back from the external I2C device.

Parameter *retries* can be used to give slow devices extra time to respond. Try an initial *retries* value of 1, and increase it if needed.

Some devices do not send an initial "ack" response. For these devices, set parameter *ignoreFirstAck* to True. This will keep the lack of an initial acknowledgement from being counted as an I2C error.

This function returns the string of bytes read back from the external I2C device.

For more information about interfacing SNAP nodes to I2C devices, refer to section 6.

i2cWrite(*byteStr, retries, ignoreFirstAck*) – I2C Write

This function can only be used after function i2cInit() has been called.

Parameter *byteStr* specifies the data to be sent to the external I2C device, including whatever "addressing" bytes must be sent to the device to get it to pay attention.

Parameter *retries* can be used to give slow devices extra time to respond. Try an initial *retries* value of 1, and increase it if needed.

Some devices do not send an initial “ack” response. For these devices, set parameter *ignoreFirstAck* to True. This will keep the lack of an initial acknowledgement from being counted as an I2C error.

This function returns the number of bytes actually written.

For more information about interfacing SNAP nodes to I2C devices, refer to section 6.

initUart(*uart*, *bps*) – Initialize a UART (short form)

This function programs the specified *uart* (0 or 1) to the specified bits per second (*bps*).

A *bps* value of 0 disables the UART.

A *bps* value of 1 selects 115,200 bps (This large number would not fit into a SNAPpy integer, and so was treated as a special case).

Usually you will set *bps* directly to the desired bits per second: 1200, 2400, 9600, etc.

NOTE – you are not limited to “standard” baud rates. If you need 1234 bps, do it.

The minimum *bps* value that can be used on the current hardware is 20 bps.

This is the short form of the initUart() function. Data Bits defaults to 8, Parity defaults to None, and Stop Bits defaults to 1.

This function returns no value.

initUart(*uart*, *bps*, *dataBits*, *parity*, *stopBits*) – Initialize a UART

This is the long form of the initUart() function just described.

This function programs the specified *uart* (0 or 1) to the specified bits per second (*bps*).
In addition, this variant of the initUart() function also allows you to specify the *dataBits* (7 or 8), the *parity* ('E', 'O', or 'N' representing EVEN, ODD, or NO parity), and the number of stop bits (only a value of 1, meaning 1 stop bit, is currently supported).

The following are the only legal combinations on the current platform:

```
initUart(uart, baud) # default to 8N1
initUart(uart, baud, 8, 'N', 1) # 8 data bits, no parity
initUart(uart, baud, 8, 'E', 1) # 8 data bits, even parity
initUart(uart, baud, 8, 'O', 1) # 8 data bits, odd parity
initUart(uart, baud, 7, 'E', 1) # 7 data bits, even parity
initUart(uart, baud, 7, 'O', 1) # 7 data bits, odd parity
```

In particular, notice that 7 data bits with NO parity is not supported (hardware limitation).

This function returns no value.

initVm() – Initialize (restart) the SNAPpy Virtual Machine

This function takes no parameters, and returns no value.

Calling this function restarts the SNAPpy virtual machine. If a SNAPpy image is currently loaded in the node, the scripts "startup" handler will be invoked, and then normal SNAPpy script execution will begin (timer hooks, GPIO hooks, STDIN hooks, etc.)

This function is normally only used by Portal and Gateway (at the end of the script upload process).

This function does not return a value.

int(*obj*) – Converts an object to numeric form (if possible)

This function was added for compatibility with Python. It converts the specified *obj* (usually a string) into numeric form. For example, int('123') = 123, int(True) = 1, and int(False) = 0.

len(*sequence*) – Returns the length of a sequence

This function was added for compatibility with Python. It returns the size of parameter *sequence*. Currently *sequence* must be a string, but this may change in a future version of SNAPpy.

As an example, len("123") = 3.

loadNvParam(*id*) – Read a Configuration Parameter from NV

This function reads a single parameter from the SNAP Node's NV storage, and returns it to the caller.

Parameter *id* specifies which parameter to read. For a full list of all the supported *id* values, refer to section 9. User parameters should have *id* values in the range 128-254.

See also function saveNvParam().

localAddr() – Get the node's SNAP address

The localAddr() function returns a string representation of the node's 3-byte address on the SNAP network.

This function takes no parameters.

mcastRpc(*group*, *ttl*, *function*, *args*…) – Multicast RPC

Call a Remote Procedure (make a Remote Procedure Call, or RPC), using multicast messaging. This means the message could be acted upon by multiple nodes.

Parameter *group* specifies which nodes should respond to the request. By default, all nodes belong to the "broadcast" group, group 0x0001. You can configure your nodes to belong to different or additional groups, refer to section 9 on Node Configuration Parameters.

Parameter *ttl* specifies the Time To Live (TTL) for the request. This basically specifies how many hops the message is allowed to make before being discarded.

Parameter *function* specifies which remote function to be invoked. This could be a built-in SNAPpy function, or one defined by the SNAPpy script currently loaded into that node.

NOTE! Except for built-ins, *what* the function actually does depends on what script is loaded into each node.

The specified function will be invoked with the parameters specified by *args*, if any *args* are present.

For example, mcastRpc(1, 3, ‘writePin’, 0, True) will ask all nodes in the broadcast group and within 3 hops of the sender to do a writePin(0, True).

mcastRpc(3, 5, ‘reboot’) will ask all nodes within 5 hops and belonging to group 1 (0x0001 or 0000000000000001b) or group 2 (0x0002 or 0000000000000010b) to do a reboot().

Notice that groups are bits, not numbers.

mcastRpc(6, 2, ‘reboot’) will ask all nodes within 2 hops and belonging to group 2 (0x0002 or 0000000000000010b) or group 3 (0x0004 or 0000000000000100b) to do a reboot().

This function normally returns True. It returns False only if it was unable to attempt the Remote Procedure Call (for example, if the node is low on memory).

If this function returns True, it does not mean your RPC request was successfully received (SNAP multicast messages are unacknowledged).

If you need confirmation the remote node executed your request, it needs to come from the remote node. Refer to the callback() function for one method of doing this.

mcastSerial(*destGroups*, *ttl*) – Setup TRANSPARENT MODE

SNAP TRANSPARENT MODE is covered in section 5.

When you want the outbound data to be sent to multiple nodes, use this function.

Parameter *destGroups* specifies the multicast groups that are eligible to receive this data. Parameter *ttl* specifies the maximum number of hops the data will be re-transmitted (in search of interested nodes).

Note that because the received serial characters will be sent using (unacknowledged) multicast messages, multicast TRANSPARENT MODE is less reliable than unicast TRANSPARENT MODE.

If you want the received serial characters to go to only one specific node, you will have to use function ucastSerial() instead.

This function does not return a value.

monitorPin(*pin*, *isMonitored*) – Enable/disable monitoring of a pin

This function can be used as an alternative to function readPin(), or in addition to it.

Parameter *pin* specifies which GPIO pin (0-18) to monitor. Parameter *isMonitored* makes the pin be monitored when True, or ignored when False.

“Monitoring” in this context means “sampled periodically in the background”, and only makes sense with pins previously configured as digital inputs via setPinDir().

> You *could* monitor an output pin, but the changes you got notified about would be changes that you *caused* (via writePin()).

When monitored pins *change state*, a HOOK_GPIN event is sent to the SNAPpy virtual machine. If you have assigned a HOOK_GPIN handler (using the “set hook” capability described in section 5), then that previously specified handler function will be invoked with the number of the GPIO pin that changed state, and the pins new value.

This function does not return a value.

See also function setRate(), which controls the *sampling rate* of the background pin monitoring that is *enabled/disabled* by this function.

ord(*str*) – Returns the integer ASCII ordinal value of a character

This function was added for compatibility with Python.

Parameter *str* specifies a single-character string to be converted. For example, ord(‘A’) = 65 (0x41), and ord(‘0’) = 48 (0x30).

peek(*address*) - Read a memory location

The peek() function allows you to read any location within the RF Engine’s 64K memory space. Parameter *address* specifies which memory location to read (0-65535).

This function returns an integer in the range 0-255.

This function is intended for advanced users only.

poke(*address*, *value*) – Write to a memory location

The poke() function allows you to write to any location within the RF Engine’s 64K memory space. Parameter *address* specifies which memory location to write to. Parameter *value* specifies the value to be written.

This function does not return a value.

This function is intended for advanced users only.

If you are not careful with this function, you could crash or even “unprogram” your RF Engine. Still, if you know what you are doing, peek() and poke() allow you to take advantage of additional hardware resources within the RF Engine itself (functions not supported by the “core” firmware).

See for example sample SNAPpy script PWM.py.

print – Generate output from your script

The print capability of SNAPpy is not really a function (you don’t put parentheses characters after it, for example), but it does let you send output from your SNAPpy scripts. Here are some examples:

```
print “hello”
print 123
print xyz
```

You can also print multiple items from a single print statement:

```
print ‘this ‘, ‘is ‘,  ‘a’,  ‘test’
```

The result of each individual print statement will usually go on a separate line. You must use a trailing comma (“,”) character to override this.

```
print “line 1”
print “line 2”
print “line 3”,
print “ and even more line 3”
```

pulsePin(*pin*, *msWidth*, *isPositive*) – Generate a timed pulse

You *could* generate a pulse using a GPIO pin, and multiple writePin() commands. This function lets you initiate the pulse in a single step, gives you finer grained control of the pulse duration, and frees your script from having to “time” (countdown) the pulse.

Parameter *pin* is which GPIO pin (0-18) to generate the pulse on. Parameter *msWidth* specifies the desired pulse width in milliseconds (1-65535)

> Specifying a pulse width of 0 will simply result in no pulse at all.

Parameter *isPositive* controls the polarity of the pulse. It essentially specifies the logic level of the leading edge of the pulse, and the opposite of this value is used for the trailing edge of the pulse.

This function has no effect unless/until the specified GPIO pin is also configured as an output (via setPinDir()).

This function does not return a value.

random() – Generate a pseudo-random number

This function returns a pseudo-random number between 0-4095.

This function does not take any parameters.

readAdc(*channel*) – Read an Analog Input pin (or reference)

This function can be called to read one of the eight external analog input pins, the internal low voltage reference, or the internal high voltage reference.

Parameter *channel* specifies which analog input channel (0-9) to read. Channels 0-7 correspond to one of the eight external analog input pins. Channel 8 refers to the internal low voltage reference. Channel 9 refers to the internal high voltage reference.

The mapping of Analog Input Channels to GPIO pins is as follows:

Analog Input Channel	**GPIO Pin**
0	18
1	17
2	16
3	15
4	14
5	13
6	12
7	11

This function returns an integer value 0-1023 (these are 10-bit analog to digital converters). Since the full-scale volage is 3.3 volts, each step represents about 3.2 millivolts.

readPin(*pin*) – Read the logic level of a pin

This function can be called for GPIO pins that are configured as digital inputs or digital outputs (see also setPinDir()).

Parameter *pin* specifies which GPIO pin (0-18) to read.

This function returns a boolean value representing the current logic level of the specified pin. For an input pin, this is a “live value”. For an output pin, this is the last value written *to* the pin.

reboot() – Schedule a reboot

This function takes no parameters, and returns no value.

Approximately 200 milliseconds after this function is called, the SNAP node will reboot.

The 200 milliseconds delay is to allow the node time to acknowledge the reboot() request.

resetVm() – Reset (shut down) the SNAPpy Virtual Machine

This function takes no parameters, and returns no value.

When this function is called, the SNAPpy Virtual Machine stops running any loaded script (but the script remains in the unit).

This function is used (by Portal and Gateway) at the start of the script upload process, and would not normally be used by users. However, sometimes when testing a script it is useful to be able to halt it.

See also function initVm(), which restarts the SNAPpy VM.

rpc(*address*, *function*, *args*…) – Remote Procedure Call (RPC)

Call a Remote Procedure (make a Remote Procedure Call, or RPC), using unicast messaging. A special packet will be sent to the node specified by parameter *address*, asking that remote node to execute the function specified by parameter *function*. The specified function will be invoked with the parameters specified by *args*, if any *args* are present.
For example, rpc('\x12\x34\x56', 'writePin', 0, True) will ask the node at address 12.34.56 to do a writePin(0, True).

rpc('\x56\x78\x9A', 'reboot') will ask the node at address 56.78.9A to do a reboot().

This function normally returns True. It returns False only if it was unable to attempt the Remote Procedure Call (for example, if the node is low on memory).

If this function returns True, it does not mean your RPC request was successfully sent and received (SNAP will give up after a programmable number of retries, which defaults to 8).

If you need confirmation the remote node executed your request, it needs to come from that remote node. Refer to the callback() function for one method of doing this.

rpcSourceAddr() – Who made this Remote ProcedureCall?

If a function on a node is invoked remotely (via RPC), then the called function can invoke function rpcSourceAddr() to find out the Network Address of the node responsible. (If you call this function when a RPC is not in progress, it just returns None).

Having this function allows a node to respond (answer back) directly to other nodes. An example will make this clearer.

Imagine node "A" is loaded with a script containing the following function definition:

```
def pong():
   print "got a response!"
```

Now imagine node "B" is loaded with a script containing the following function:

```
def ping():
   rpc( rpcSourceAddr(), 'pong')
```

Node "A" can invoke function "ping" on node "B", but it has to know node B's address to do so:

```
rpc(node_B_address_goes_here, 'ping')
```

When node "B" receives the RPC request packet, it will invoke local function 'ping', which will generate the remote 'pong' request. *Notice that node "B" can respond to a 'ping' request from any node*.

All SNAP Network Addresses are three-byte strings.

This function takes no parameters.

rx(*isEnabled*) – Turn radio receiver on or off

This function allows you to power down the radio, extending battery life in applications that do not actually need the radio (or only need it intermittently).

NOTE! If you turn the radio off (using rx(False)), then you <u>will not</u> receive any more radio traffic!

The radio defaults to ON in SNAP Nodes. If you invoke rx(False), the radio will be powered down. Invoking rx(True) will power the radio back up.

In addition, *sending* any data over the radio will automatically wake the radio back up.

To be clear: a node can wake up its own radio by attempting to transmit. A node's radio will **not** be woken up by transmissions from other nodes. This function does not return a value.

saveNvParam(*id*, *obj*) – Save data into NV memory

This function lets you store individual pieces of data into the SNAP node's Non-Volatile (NV) memory.

Parameter *id* specifies which "key" to store the *obj* parameter under. NV parameter IDs 0, 255, and 1-127 all have pre-assigned meanings (refer to section 9). IDs 128-254 are user defined, your script can store whatever you want, under any ID (128-254) that you want.

The *obj* parameter should be the data you want to store, and can be a boolean, an integer, or a string.

See also function loadNvParam().

This function does not return a value.

scanEnergy() – Get energy readings from all 16 channels

The getEnergy() function returns the result of a brief 802.15.4 Energy Detection scan (on the current channel).

Function scanEnergy() is an extension of getEnergy(). It essentially calls getEnergy() 16 times in a row, changing the channel before each getEnergy() scan.
Function scanEnergy() returns a 16-byte string, where the first character corresponds to the "detected energy level" on channel 0, the next character goes with channel 1, and so on.

The units for the "detected energy level" are the same as that returned by getLq(), refer to the documentation on that function for more info.

This function takes no parameters.

setChannel(*channel*) – Specify which channel the node is on

The setChannel() function takes a channel parameter 0-15 representing which SNAP channel the node should switch to.

SNAP channel 0 corresponds to 802.15.4 channel 11, 1 to 12, and so on. Refer to the description for function getChannel() for more on this topic.

This function returns no value.

Note that this function changes the "live" channel setting, and the effect only lasts until the next reboot or power cycle. You can also use saveNvParam() to save the "persisted" channel setting, if you want the node to *stay* on that channel.

Applications wanting to change the channel *now* plus *going forward* should probably use both functions.

This function does not return a value.

setNetId(*networkId*) – Specify which Network ID the node is on

The setNetId() function takes a channel parameter 0-0xFFFF representing which SNAP Network ID the node should switch to. Note that Network ID 0xFFFF is considered a “wildcard” network ID (matches all nodes), and you normally should only use network IDs of 0-0xFFFE.

This function returns no value.

Note that this function changes the “live” network ID setting, and the effect only lasts until the next reboot or power cycle. You can also use saveNvParam() to save the “persisted” network ID setting, if you want the node to *stay* on that network ID.

Applications wanting to change the network ID *now* plus *going forward* should probably use both functions.

setPinDir(*pin*, *isOutput*) – Set direction (input or output) for a pin

This function should be called for each GPIO pin you want to use as either a digital input or digital output in your application.

Parameter *pin* specifies which GPIO pin (0-18) to configure. Parameter *isOutput* makes the pin be an output when True, or an input when False.

For a given GPIO pin, you should call this function before calling functions like setPinPullup(), readPin() and monitorPin() (for input pins) or setPinSlew(), writePin() and pulsePin() (for output pins).

This function does not return a value.

setPinPullup(*pin*, *isEnabled*) – Control internal pullup resistor

This function should be called for each GPIO pin you are using as a digital input, if you want the internal pullup resistor (~25K) for that pin to be enabled. (The default pullup setting is off, so you usually do not have to call this function unless you *want* the pullup enabled), or you previously enabled it and now want to disable it.

Parameter *pin* specifies which GPIO pin (0-18) to configure. Parameter *isEnabled* makes the internal pullup for the pin be active when True, or inactive when False.

This function has no effect unless/until the pin is also configured as a digital input pin.

This function does not return a value.

setPinSlew(*pin, isRateControl*) – Enable/disable slew rate control

This function should be called for each GPIO pin you are using as a digital output, if you want the internal slew rate control (~30ns) for that pin to also be enabled. (The default slew rate setting is off, so you usually do not have to call this function unless you *want* the slew rate control enabled).

Parameter *pin* specifies which GPIO pin (0-18) to configure. Parameter *isRateControl* makes the slew rate control be active when True, or inactive when False.

This function has no effect unless/until the pin is also configured as a digital output pin.

This function does not return a value.

setRate(*rate*) – Set monitorPin() sample rate

By default, the background pin sampling that is enabled/disabled by function monitorPin() takes place 10 times a second (every 100 milliseconds). This function allows you to vary that sampling rate.

Parameter *rate* specifies whether the sampling should be OFF (*rate* =0), every 100 ms (*rate* = 1), every 10 ms (*rate* = 2), or every 1 ms (*rate* = 3).

This function has no effect unless/until you are actually using pin monitoring.

This function does not return a value.

setSegments(*segments*) – Update seven-segment display

This function is only useful on Synapse boards that have a seven-segment (per digit) display on them. It assumes a particular type of “shift register controlled” display, that requires continuous refresh, with GPIO pins 13 and 14 controlling the display.

Parameter *segments* specifies a 16-bit binary pattern that controls which segments will be lit, and which will be dark. Because the displays currently used do not have decimal points, only 14 of the total 16 bits are meaningful.

A *segments* value of 0x0000 turns off all segments. A value of 0x7F7F corresponds to “all segments on”.

This interface gives you complete control of the display, but you can wrap the display in higher level access functions. See for example function display2digits() in supplied script evalBase.py.

The actual “bit to segment” assignments make sort of a “clockwise inward spiral” path around each digit.

Refer to the table on the following page for more details.

<table>
<tr><th>Bit (in hexadecimal)</th><th>Bit Position Within Display</th><th>Bit (in hexadecimal)</th><th>Bit Position Within Display</th></tr>
<tr><td>0x0001</td><td>- -
| | | |
- -
| | | |
- -</td><td>0x0002</td><td>- -
| | | |
- -
| | | |
- -</td></tr>
<tr><td>0x0004</td><td>- -
| | | |
- -
| | | |
- -</td><td>0x0008</td><td>- -
| | | |
- -
| | | |
- -</td></tr>
<tr><td>0x0010</td><td>- -
| | | |
- -
| | | |
- -</td><td>0x0020</td><td>- -
| | | |
- -
| | | |
- -</td></tr>
<tr><td>0x0040</td><td>- -
| | | |
- -
| | | |
- -</td><td>0x0080

(no effect)</td><td>- -
| | | |
- -
| | | |
- -</td></tr>
<tr><td>0x0100</td><td>- -
| | | |
- -
| | | |
- -</td><td>0x0200</td><td>- -
| | | |
- -
| | | |
- -</td></tr>
<tr><td>0x0400</td><td>- -
| | | |
- -
| | | |
- -</td><td>0x0800</td><td>- -
| | | |
- -
| | | |
- -</td></tr>
<tr><td>0x1000</td><td>- -
| | | |
- -
| | | |
- -</td><td>0x2000</td><td>- -
| | | |
- -
| | | |
- -</td></tr>
<tr><td>0x4000</td><td>- -
| | | |
- -
| | | |
- -</td><td>0x8000

(no effect)</td><td>- -
| | | |
- -
| | | |
- -</td></tr>
</table>

sleep(*mode*, *ticks*) – Go to sleep (enter low-power mode)

This function puts the radio and CPU on the SNAP node into a low-power mode for a specified number of *ticks*. This is used to extend battery life.

Parameter *mode* chooses from two possible sleep modes:

0 – the radio is put completely to sleep (the processor measures time)

Parameter *ticks* is in units of 1.024 seconds
The timing in this node is much less accurate (+/- 30%)
If you only sleep for one tick, this mode uses less power than mode 1
If you are sleeping for more than one tick, this mode uses more power
You can sleep for up to 32767 *ticks* using this mode

1 – the radio stays awake just enough to "count down" the sleep interval

Parameter *ticks* is in units of 1.0 seconds
The timing in this mode is more accurate
If you are only sleeping for 1 *tick*, this mode uses more power than mode 0
If you are sleeping for more than 1 *tick*, this mode uses less power
You can sleep for up to 1073 *ticks* using this mode

A *ticks* parameter of 0 can be used to sleep until a button is pressed (see script pinWakeup.py), but SNAPpy is smart enough to know if you have *not* enabled a wakeup pin, and will **ignore** a sleep(*mode*, 0) if there is no wakeup possible.

This function does not return a value.

spiInit(*cpol*, *cpha*, *isMsbFirst*, *isFourWire*) – Setup SPI Bus

This function initializes the SNAP node to perform Serial Peripheral Interface (SPI) Bus interfacing.

The SPI standard has multiple options, hence the large number of parameters in spiInit().

Parameter *cpol* refers to Clock Polarity, and can be either True or False.

Parameter *cpha* refers to the Clock Phase, and can be True (rising edge) or False (falling edge).

Parameter *isMsbFirst* controls the order in which individual bits within each byte will be shifted out. Setting this parameter to True will make the 0x80 bit go out first, setting this parameter to False will make the 0x01 bit go out first.

Parameter *isFourWire* lets you select the variant of SPI you are connecting to. Three wire SPI omits the MISO pin. In three-wire SPI, even if the slave does send data, it is over the MOSI pin.

This function does not return a value.

spiRead(*byteCount*, *bitsInLastByte*=8) – SPI Bus Read

This function can only be used after function spiInit() has been called.

This function reads data from a three wire SPI device (for four wire SPI, you should be using the bidirectional function spiXfer() instead).

Parameter *byteCount* specifies how many bytes to read.

Parameter *bitsInLastByte* makes it possible to accommodate devices with data widths that are not multiples of 8 (like 12 bits). The default value of *bitsInLastByte* is 8. For a device with a data width of 12 bits, *bitsInLastByte* would be set to 4. For a device with a data width of 31 bits, *bitsInLastByte* would be set to 7.

The order that bits get shifted in depends on the value of parameter *isMsbFirst* which was specified in the previous spiInit() call.

This function returns a string containing the actual bytes received.

More background information on using SPI is in section 6.

spiWrite(*byteStr*, *bitsInLastByte*=8) – SPI Bus Write

This function can only be used after function spiInit() has been called.

This function writes data to a three or four wire SPI device. If you want to write and read data simultaneously (four wire SPI only), then you should be using the bidirectional function spiXfer() instead of this one).

Parameter *byteStr* specifies the actual bytes to be shifted out.

Parameter *bitsInLastByte* makes it possible to accommodate devices with data widths like 12 bits. The default value of *bitsInLastByte* is 8. For a device with a data width of 12 bits, *bitsInLastByte* would be set to 4. For a device with a data width of 31 bits, *bitsInLastByte* would be set to 7.

The order that bits get shifted out depends on the value of parameter *isMsbFirst* which was specified in the previous spiInit() call.

This function does not return a value.

More background information on using SPI is in section 6.

spiXfer(*byteStr*, *bitsInLastByte*=8) – Bidirectional SPI Transfer

This function can only be used after function spiInit() has been called.

This function reads and writes data over a four wire SPI device. If your device is read-only or write-only, you should look at the spiRead() and spiWrite() routines.

Parameter *byteStr* specifies the actual bytes to be shifted out.

As these bits are being shifted out to the slave device (on the MOSI pin), bits from the slave device (on the MISO pin) are simultaneously shifted in.

Parameter *bitsInLastByte* makes it possible to accommodate devices with data widths like 12 bits. The default value of *bitsInLastByte* is 8. For a device with a data width of 12 bits, *bitsInLastByte* would be set to 4. For a device with a data width of 31 bits, *bitsInLastByte* would be set to 7.

The <u>order</u> that bits get shifted out depends on the value of parameter *isMsbFirst* which was specified in the previous spiInit() call.

This function returns a byte string consisting of the bits that were shifted in (as the bits specified by paramter *byteStr* were shifted out).

More background information on using SPI is in section 6.

stdinMode(*mode*, *echo*) – Set console input options

This function controls how serial data gets presented to your SNAPpy script (via the HOOK_STDIN), and how it appears to the user.

Parameter *mode* chooses between line-at-a-time (*mode* = 0) or character based (*mode* = 1).

In "line mode" (mode 0), characters are buffered up until either a Carriage Return (CR) or Line Feed (LF) are received. The complete string is then given to your SNAPpy script in a single HOOK_STDIN invocation. Note that **either** character can trigger the handoff, so if your terminal (or terminal emulator) is automatically adding extra CR or LF characters, you will see additional empty strings ("") passed to your script.

> The character sequence A B C CR LF looks like two lines of input to SNAPpy.

In "character mode" (mode 1), characters are passed to your SNAPpy script as soon as they become available. If characters are being received fast enough, it still is possible for your script to receive more than one character at a time, they are just not buffered waiting for a CR or LF.

Parameter *echo* is a Boolean parameter that controls whether or not the SNAP firmware will "echo" (retransmit) the received characters back out (so that the user can see what they are typing).

This function does not return a value.

str(*object*) – Returns the string representation of an object

This function was included for compatibility with Python.

Function str() returns a string based on the value of the object you give it.

For example, str(123) = ‘123’, str(True) = ‘True’, and str(‘hello’) = ‘hello’.

txPwr(*power*) – Set Radio TX power level

The 802.15.4 radio on the SNAP node defaults to full power. Function txPwr() lets you reduce the power level from this default maximum.

Parameter *power* specifies a transmit power level from 0-17, with 0 being the lowest power setting and 17 being the highest power setting.

This function does not return a value.

ucastSerial(*destAddr*) – Setup outbound TRANSPARENT MODE

SNAP TRANSPARENT MODE is covered in section 5.

When you want the outbound data to be sent to a specific node, use this function.

Parameter *destAddr* specifies the Network Address of some other node to give the received serial characters to.

If you want the received serial characters to go to more than one node, you will have to use function mcastSerial() instead.

This function does not return a value.

uniConnect(*dest*, *src*) – Make a one-way switchboard connection

The SNAPpy switchboard is covered in section 5.

This function establishes a one-way connection between two points. See included script switchboard.py for the possible values of parameters *src* and *dest*.

See also function crossConnect() if you need a bi-directional hookup. As an alternative, two uniConnect() calls can be equal to one crossConnect() call. For example:

```
uniConnect(UART1, UART2)
uniconnect(UART2, UART1)
```

has the same effect as:

```
crossConnect(UART1, UART2)
```

This function does not return a value.

vmStat(*statusCode, args*…) – Back door used by Portal

This function was originally only used by Portal, and was undocumented in version 2.0.

With the addition of the SNAP Gateway to the Synapse product line, customers started needing access to the same functionality Portal uses.

> This function is in some aspects a precursor to the version 2.1 callback() function.

Originally added to support initial discovery of nodes, and downloading of SNAPpy scripts, this function has grown over time. Now vmStat() can trigger several actions, or retrieve several types of data.

Parameter *statusCode* controls what actions will be taken, and what data will be returned (via a tellVmStat() callback to the original node).

The currently supported *statusCode* values are:

0 = VM_RESET: stop the SNAPpy Virtual Machine (for script uploading)
1 = VM_IMG_ERASE: erase the current SNAPpy script
2 = VM_WR_BLK: used when uploading scripts - DO NOT CALL THIS!
3 = VM_INIT: restart the SNAPpy Virtual Machine (after script uploading)
4 = VM_NVREAD: read the specified NV Parameter
5 = VM_NAME: returns NODE NAME if set, else IMAGE NAME, plus Link Quality
6 = VM_VERSION: returns software version number
7 = VM_NET: returns Network ID and Channel
8 = VM_SPACE: returns Total Image (script) Space Available
9 = VM_SCAN: scans all 16 channels for energy, returns 16 character string
10 = VM_INFO: returns Image Name (script name) and Link Quality

You probably should not be invoking **vmStat**() with statusCodes of 0-3 (unless you are implementing your own downloader).

statusCodes 4-10 are safe to call.
After the statusCode, the next argument varies (depending on the statusCode).

After the "varying" argument comes a final optional argument that specifies a "time window" to randomly reply within (more about this below).

For VM_NVREAD, the second argument is the ID of the NV Parameter you want to read (these are the same IDs used in the saveNvParam() and loadNvParam() functions). You can also optionally specify a "reply window".

The NV Parameter IDs are given in section 9.

The reported values will be a "hiByte" of the NV Parameter ID, and a "data" of the actual NV Parameter value.

For VM_NAME, the only parameter is the optional reply window.

The reported "data" value will be a string name and a Link Quality reading.

For VM_VERSION, the only parameter is the optional reply window.

The reported "data" value will be a version number string

For VM_NET, the only parameter is the optional reply window.

The reported values will be a "hiByte" containing the currently active channel (0-15), and a "data" value of the current Network ID

For VM_SPACE, the only parameter is the optional reply window.

The reported "data" value will be the Total Image (script) Space Available

For VM_SCAN, the only parameter is the optional reply window.

The reported "data" value will be a 16 character string containing the detected energy levels on all 16 channels. Note that each scan just represents one point in time, you will probably have to initiate multiple scans to determine which channels actually have SNAP nodes on them.

You can see this VM_SCAN function put to use in the *Channel Analyzer* feature of Portal.

See also function scanEnergy(), which returns data in an equivalent format.

For VM_INFO, the only parameter is the optional reply window.

The reported values will be a "hiByte" of the current Link Quality, and a "data" of the currently loaded script name (a string).

Return value format:

All of the VM_xxx functions invoke a callback named tellVmStat(*word*, *data*)

The least significant byte of *word* will be the originally requested *statusCode*. The most significant byte will vary depending on the *statusCode*, and is the "hiByte" described above. The *data* value is the main return value, and is also dependant on the *statusCode*.

Return value timing:

If you do not specify a "time window" parameter, the nodes will respond immediately.

Some of these commands are multicast by Portal, and we needed a way to keep all of the nodes from trying to respond at once.

Specifying a non-zero "time window" tells the node to pick a random time within the next "time window" seconds, and wait until then to reply.

This function does not return a value, but it causes a tellVmStat() call to be made to the node that requested the vmStat().

NOTE – now that the callback() function has been added, some of the vmStat() capabilities are redundant.

writeChunk(*offset*, *data*) – Synapse Use Only

This function is used by Portal and Gateway as part of the script uploading process.

There should be no reason for user scripts to call this function, and attempting to do so could erase or corrupt all of your SNAP firmware, requiring a firmware reload (Portal has the capability to do this).

This function does not return a value.

writePin(*pin*, *isHigh*) – Set output pin level

This function allows you to control digital output pins (GPIO pins configured as digital outputs).

Parameter *pin* specifies which GPIO pin (0-18) to control. Parameter *isHigh* makes the pin go high (True) or low (False).

This function has no effect unless/until the pin is configured as a digital output pin via setPinDir(). See also related function setSlewRate(), which controls how quickly the pin will transition to a new value..

This function does not return a value.

Here are the functions again, but this time broken down by category.

ADC

readAdc(*channel*)	Sample ADC on specified input channel, returns 10 bit unsigned

Note: *channel is 0-9. Channels 0-7 are external analog inputs.*
Channel 8 is an internal low voltage reference.
Channel 9 is an internal high voltage reference.

NOTE: All ADC readings (even channel 9) are relative to VCC (not absolute). You may require an external reference voltage for comparision.

CBUS Master Emulation

cbusRd(*numToRead*)	Reads *numToRead* bytes from CBUS, returns string
cbusWr(*byteStr*)	Writes every byte in *byteStr* to the CBUS

These functions are discussed in section 6 of this document.

GPIO

setPinDir(*pin*, *isOutput*)	Set direction for parallel I/O pin
setPinPullup(*pin*, *isEnabled*)	Enable pullup resistor (25k) for Input pin
setPinSlew(*pin*, *isRateControl*)	Enable slew rate-control (30ns) for Output pin
monitorPin(*pin*, *isMonitored*)	Enable GPIN events on Input pin
pulsePin(*pin*, *msWidth*, *isPositive*)	Apply pulse to Output pin
readPin(*pin*)	Read current level of pin
writePin(*pin*, *isHigh*)	Set Output pin level
setRate(*rateCode*)	Set pin sampling rate to off (0), 100 ms (1), 10 ms (2), or 1 ms (3)

I2C Master Emulation

getI2cResult()	Returns the result of the most recent I2C operation
i2cInit(*enablePullups*)	Prepare for I2C operations
i2cRead(*str*, *numBytes*, *retries*, *ignoreFirstAck*)	Write *str* out, then read *numBytes* back in from I2C bus. Parameters *retries* and *ignoreFirstAck* are used with slow or special case devices
i2cWrite(*str*, *retries*, *ignoreFirstAck*)	Write *str* out over the I2C bus. Parameters *retries* and *ignoreFirstAck* are used with slow or special case devices

These functions are discussed in section 6 of this document.

Misc

setSegments(*segments*)	Set eval-board LED segments (clockwise bitmask)
bist()	Built-in self test
eraseImage()	Erase user-application FLASH memory
resetVm()	Reset the embedded virtual machine (prep for upload)
initVm()	Initialize embedded virtual machine
vmStat(*statusCode, args...*)	Solicit a tellVmStat for system parameters
writeChunk(*ofs, str*)	Write string to user-application FLASH memory
chr(*number*)	Returns the character string representation of "number"
str(*obj*)	Returns the string representation of *obj*
int(*obj*)	Returns the integer representation of *obj*
len(*str*)	Returns the length of string *str* (0-255)
random()	Returns a pseudo-random number 0-4095
stdinMode(*mode,echo*)	*mode* is 0 for line, 1 for character at a time *echo* is True or False

Network

getNetId()	Current Network ID
setNetId(*netId*)	Set Network ID (1-65535)
localAddr()	Local network address (3-byte binary string)
rpcSourceAddr()	Originating address of current RPC context (None if called outside RPC)
mcastSerial(*dstGroups, ttl*)	Set Serial transparent mode to multicast
ucastSerial(*dstAddr*)	Set Serial transparent mode to unicast
callback(*callbackFnObj, remoteFnObj, args...*)	Remote Procedure Call of Remote Procedure Call results
rpc(*dstAddr, remoteFnObj, args...*)	Remote Procedure Call (unicast)
mcastRpc(*dstGroups, ttl, remoteFnObj, args...*)	Remote Procedure Call (multicast)

Non-Volatile (NV) Parameters

loadNvParam(*id*)	Load indexed parameter from NV storage
saveNvParam(*id, obj*)	Save object to indexed NV storage location

Radio

rx(*isEnabled*)	Enable/disable radio receiver
tx(*power*)	Adjust radio transmit level (0 is lowest, 17 is highest)
setChannel(*channel*)	Set radio channel (0-15)
getChannel()	Radio channel (0-15)
getLq()	Link Quality in (-) dBm
getEnergy()	Detected RF energy in (-) dBm (current channel)
scanEnergy()	Detected RF energy in (-) dBm (all 16 channels)

Most applications need the radio to be on full-time (so the nodes can talk to each other). If your application requires no wireless communications, you can reduce power consumption (increasing battery life) by invoking rx(False) to turn off the radio.

SPI Master Emulation

spiInit(*cpol, cpha, isMsbFirst, isFourWire*)	setup for SPI, with specified Clock Polarity, Clock Phase, Bit Order, and Physical Interface
spiRead(*byteCount, bitsInLastByte*)	receive data in from SPI - returns response string (three wire SPI only)
spiWrite(*byteStr, bitsInLastByte*)	send data out SPI - *bitsInLastByte* defaults to 8, can be less
spiXfer(*byteStr, bitsInLastByte*)	bidirectional SPI transfer - returns response string (four wire SPI only)

These functions are discussed in section 6 of this document.

Switchboard

crossConnect(*dataSrc1, dataSrc2*)	Cross-connect SNAP data-sources
uniConnect(*dst, src*)	Connect src->dst SNAP data-sources

You use crossConnect() to setup bidirectional transfers. You use uniConnect() to setup a one-way connection. Note that multiple sources can be uni-connected to the same destination.

System

getMs()	Elapsed milliseconds since startup (16bit)
getInfo(*which*)	Get specified system info
getStat(*which*)	Get debug info (Synapse developer use only)
call()	Invoke a user-defined binary function
peek(*addr*)	Read a memory location
poke(*addr, byteVal*)	Write a memory location
errno()	Read and reset last error code
imageName()	Name of current SNAPpy image
random()	Returns a pseudo-random number (0-4095)
reboot()	Reboot the device
sleep(*mode,ticks*)	Enter sleep mode for specified number of ticks In mode 0, ticks are 1.024 seconds each In mode 1, ticks are 1 second each, and can be 0-1073

UARTs

initUart(*uartNum, bps*)	Enable UART at specified rate (zero rate to disable)
initUart(*uartNum, bps, dataBits, parity, stop*)	Enable UART at specified rate (zero rate to disable), data bits, parity, and stop bits
flowControl(*uartNum, isEnabled*)	Enable RTS/CTS flow control

Note*: uartNum is 0 or 1*

8. SNAPpy Scripting Hints

The following are some helpful hints for developing custom SNAPpy scripts for your nodes. These are not in any particular order.

Beware of Case SensitiViTy

Like “desktop” Python, SNAPpy scripts are case sensitive – “foo” is not the same as “Foo”.

Also, because SNAPpy is a dynamically typed language, it is perfectly legal to invent a new variable on-the-fly, and assign a value to it. So, the following SNAPpy code snippet:

```
foo = 2
Foo = 3
```

…results in two variables being created, and “foo” still has the original value of 2.

Case sensitivity applies to function names as well as variable names.

```
linkQuality = getlq()
```

…is a script error. The built-in function is not named “getlq”.

```
linkQuality = getLq()
```

…is what you want.

Beware of Accidental Local Variables

SNAPpy functions can access global variables, but (as in Python) you need to use the “global” keyword in your functions.

```
count = 4

def bumpCount():
    count = count + 1
```

…is not going to do what you want (count will still equal 4). Instead, write something like:

```
count = 4

def bumpCount():
    global count
    count = count + 1
```

Don’t Cut Yourself Off (Packet Serial)

Portal talks to its “bridge” (directly connected) node using a packet serial protocol.

SNAPpy scripts can change both the UART and Packet Serial settings.

This means you can be talking to a node from Portal, and then upload a script into that node that starts using that same serial port for some other function (for example, for script text output). Portal will no longer be able to communicate with that node serially.

Remember Serial Output Takes Time

A script that does:

```
print “imagine a very long and important message here”
sleep()
```

…might not be allowing enough time for the text to make it *all the way out of the node* (particularly at slower baud rates) before the sleep() command shuts the node off.

One possible solution would be to invoke the sleep() function from the timer hook.

In the script startup code:

```
sleepCountDown = 0
```

In the code that used to do the “print + sleep”

```
global sleepCountDown

print “imagine a very long and important message here”
sleepCountDown = 500 # actual number of milliseconds TBD
```

In the timer code:

```
global sleepCountDown

if sleepCountDown > 0:
    if sleepCountDown < 100: # timebase is 100 ms
        sleepCountDown = 0
        sleep()
    else:
        sleepCountDown -= 100
```

Remember nodes do not have a lot of RAM

SNAPv2 RF Engines only have 2-4K of Random Access Memory.

SNAPpy scripts should avoid generating a flood of text output all at once (there will be no where to buffer the output). Instead, generate the composite output in small pieces (for example, one line at a time), triggering the process with the HOOK_STDOUT event.

If a script generates too much output at once, the excess text will be truncated.

Remember SNAPpy Numbers Are Integers

2/3 = 0 in SNAPpy. As in all fixed point systems, you can work around this by “scaling” your internal calculations up by a factor of 10, 100, etc. You then scale your final result down before presenting it to the user.

Remember SNAPpy Integers are Signed

SNAPpy integers are 16-bit numbers, and have a numeric range of -32768 to +32767.

Be careful that any intermediate math computations do not exceed this range, as the resulting overflow value will be incorrect.

Remember SNAPpy Integers have a Sign Bit

Another side-effect of SNAPpy integers being signed – negative numbers shifted right are still negative (the sign bit is preserved).

You might expect 0x8000 >> 1 to be 0x4000 but really it is 0xC000. You can use bitwise and-ing to get the desired effect if you need it.

```
X = X >> 1
X = X & 0x7FFF
```

Pay Attention to Script Output

Any SNAPpy script errors (see section 4) that occur will be printed to the previously configured STDOUT destination, such as serial port 2. If your script is not behaving as expected, be sure and check the output for any errors that may be reported.

If the node having the errors is a remote one (you cannot *see* its script output), remember that you can invoke the “Intercept STDOUT” action from the **Node Info** tab for that node. The error messages will then appear in the Portal event log.

Don’t Define Functions Twice

In SNAPpy (as in Python), defining a function that already exists counts as a re-definition of that function.

Other script code, that used to invoke the old function, will now be invoking the replacement function instead.

Using meaningful function names will help alleviate this.

There is no <u>truly</u> dynamic memory in SNAPpy

SNAPpy scripts support some functions that in “desktop Python” require the use of dynamic memory allocation. The core SNAP code does not support dynamic memory allocation. To implement these functions, a handful of temporary buffers are used.

One such temporary buffer is used for string concatenation (a = ‘hello’ + ‘ world’). This buffer is only 64 bytes, so keep your concatenated strings short. Also realize that the temporary buffer is just that: *temporary*. The *next* string concatenation done by your script will overwrite the previous one.

a = ‘hello’ + ‘ world’
b = ‘goodbye’ + ‘ mars’

At this point, **both** a and b are pointing at “goodbye mars”.

You can use string concatenation, but be careful how long you try to keep the results.

Another temporary buffer (also 64 bytes long) is used by the Python “slicing” operator. So you can extract a substring from another string, but it needs to be 64 characters or less, plus you should treat it as the temporary result it is. Use it or lose it!

a = ‘abcdef’
b = a[0:3]
c = a[1:4]

At this point, **both** b and c are pointing at “bcd”.

You can use string slicing, but be careful how long you try to keep the results.

There is a small one character buffer that is used when extracting a single character from another string (subscripting).

a = “hello”
b = a[4]
c = a[1]

At this point, both b and c are equal to “e”.

Finally, the chr() function also uses a temporary one character buffer.

a = chr(65)
b = chr(66)

At this point, both a and b are equal to “B”

Try to use these “temporary values” as soon as you create them. If you must have a persistent value, try saving the string as a NV parameter by using the SNAPpy API functions saveNvParam() and loadNvParam().

NV Parameters must be used carefully too

Because of FLASH memory compaction and relocation that can occur as new NV parameters are saved, you should always read in (using loadNvParam(id)) a NV parameter right before you need it.

Use the Supported Form of Import

In SNAPpy scripts you should use the form:

```
from moduleName import *
```

Remember Portal Speaks Python Too

SNAPpy scripts are a very powerful tool, but the SNAPpy language is a modified subset of full-blown Python.

In some cases, you may be able to take advantage of Portal’s more powerful capabilities, by having SNAPpy scripts (running on remote nodes) invoke routines contained within Portal scripts.

This applies not only to the scripting language differences, but also to the additional hardware a desktop platform adds.

As an example, even though a node has no graphics display, it can still generate a plot of *link quality* over time, by using a code snippet like the following:

```
rpc("\x00\x00\x01", "plotlq", localAddr(), getLq())
```

For this to do anything useful, Portal must also have loaded a script containing the following definition:

```
def plotlq(who,lq):
  logData(who,lq,256)
```

The node will report the data, and Portal will plot the data.

Remember you can invoke functions remotely

Writing modular code is always a good idea. As an added bonus, if you are able to break your overall script into multiple function definitions, you can remotely invoke the individual routines. This can help in determining where any problem lies.

Be careful using multicast RPC invocation

Realize that if you multicast an RPC call to function "foo", *all* nodes in that multicast group that have a foo() function will execute theirs. To put it another way, give your SNAPpy functions distinct and meaningful names.

If all nodes hear the question at the same time, they will all answer at the same time

If you have more than a few nodes, you will need to coordinate their responses (using a SNAPpy script) if you poll them via a multicast RPC call.

9. SNAP Node Configuration Parameters

You make your SNAP nodes do completely new things by loading SNAPpy scripts into them. You can often adjust the way they do the things that are already built-in by adjusting one or more *Configuration Parameters*.

These *Configuration Parameters* are stored in a section of Non-Volatile (NV) memory within the SNAP node. For this reason *Configuration Parameters* are also referred to as *NV Parameters*.

SNAPpy scripts can access these NV Parameters by using the loadNvParam(*id*) function.

SNAPpy scripts can change these parameters by using the saveNvParam() function (and then rebooting so that the changes will take effect).

When using the loadNvParam() and saveNvParam() functions, you must specify *which* NV Parameter by *numeric ID*.

You can also easily view and edit these parameters using Portal, refer to section 13 of this manual. When you view and edit these parameters from Portal, you do not need to know the NV Parameter ID, Portal takes care of that for you.

Here are all of the NV Parameters (sorted by numeric ID), and what they do.

> **Remember – you must reboot a node after changing any NV Parameter for the change to actually take effect.**

ID 0 – **reserved for internal use** (0 means "erased" inside the actual NV storage)

ID 1 – **reserved for internal use** (used to support a NV page-swapping scheme internally)

ID 2 – **MAC Address** – the eight byte address of the SNAP Node

ID 3 – **Network ID** – the 16-bit Network Identifier of the SNAP Node

ID 4 – **Channel** – the channel (0-15) the SNAP Node is on

ID 5 - **Multi-cast Processed Groups** – This is a 16-bit field controlling which multi-cast groups the node will respond to. It is a bit mask, with each bit representing one of 16 possible multi-cast groups. For example, the 0x0001 bit represents the "broadcast group".

One way to think of groups is as "logical sub-channels" or as "subnets". By assigning different nodes to different groups, you can further subdivide your network.

For example, Portal could multi-cast a "sleep" command to group 0x0002, and ***only*** nodes *with that bit set* in their **Multi-cast Processed Groups** field would go to sleep.

Note that a single node can belong to any (or even all) of the 16 groups.

ID 6 - **Multi-cast Forwarded Groups** - This is a separate 16-bit field controlling which multi-cast groups will be *re-transmitted* (forwarded) by the node.

By default, all nodes process and forward group 1 (*broadcast*) packets.

Please note that these two fields are independent of each other. A node could be configured to forward a group, process a group, or both.

ID 7 – **Manufacturing Date** – Synapse use only

ID 8 – **Device Name** – New for version 2.1, this NV Parameter lets you choose a name for the node, rather than letting it be determined by what *script* happened to be loaded in the node at the time Portal first detected it. If this parameter is set to None, then the old behavior will be used, you do not *have* to give your nodes explicit names.

ID 9 – **Last System Error** – if a SNAP Node does a "panic" reboot, it stores the error code telling *why* here in this NV Parameter (Synapse internal use only).

ID 10 - **Device Type** – This is a user definable string that can be read by scripts. This allows a single script to fill multiple roles, by giving it a way to determine "which type of node it is running on". This NV Parameter gives you a way to "categorize" your nodes.

ID 11 - **Feature Bits** control some miscellaneous hardware settings. The individual bits are:

Bit 0 (0x0001) – Enable Serial Port 1 (USB port on a SN111 board)
Bit 1 (0x0002) – Enable hardware flow control on Serial Port 1
Bit 2 (0x0004) – Enable Serial Port 2 (RS-232 port on a SN111 or SN171 board)
(the *only* serial port on a SN171 Proto Board)
Bit 3 (0x0008) – Enable hardware flow control on Serial Port 2
Bit 4 (0x0010) – Enable the radio Power Amplifier (PA)

Units with PA hardware can be identified by the "RFET" on their labels. Units without PA hardware say "RFE" instead of "RFET".

The PA feature bit should only be set on "RFET" units. Setting this bit on a "RFE" board will not harm the RF Engine, but will actually result in <u>lower</u> transmit power levels (a 20-40% reduction).

ID 12 - **Default UART** - controls which UART will be pre-configured for Packet Serial Mode.

Normally the UART related settings would be specified by the SNAPpy scripts uploaded into the node. This *default setting* has been implemented to handle nodes that *have no scripts loaded yet*.

These defaults are overridden when needed!

Although you can request that one or both UARTs are disabled (via the **Feature Bits**), and you can request that there is no Packet Serial mode UART (via the **Default UART** parameter), both of these user requests will be ignored *unless there is also* a valid SNAPpy script loaded into the unit.

If there is *no* SNAPpy script loaded, a fail-safe mechanism kicks in and **forces** an active Packet Serial port to be initialized, regardless of the configuration settings. This was done to help prevent users from "locking themselves out".

If there *is* a SNAPpy script loaded, then the assumption is that the *script* will take care of any configuration overrides needed, and the **Feature Bits** and the **Default UART** setting will be honored.

ID 13 **– Buffering Timeout –** This lets you tune the overall serial data timeout.

This value is in milliseconds, and defaults to 5. This value controls the maximum amount of time between an initial character being received over the serial port, and a packet of buffered serial data being transmitted.

Note that other factors can also trigger the transmission of the buffered serial data, in particular see the next two NV Parameters.

The larger this value is the more buffering will take place. Every packet has 12-15 bytes of overhead, so sending more serial characters per packet makes TRANSPARENT MODE more efficient. Also, when using MULTICAST TRANSPARENT MODE, keeping the characters together (in the same packet) improves overall reliability.

The tradeoff is that the larger this value is, the greater the maximum latency can be through the overall system.

ID 14 **– Buffering Threshold –** serial data threshold

This value is in total packet size, and defaults to 75 bytes. This value includes the packet headers, so the actual amount of serial data sent in each packet will be less than this number.

The maximum SNAP packet size is 123 bytes. If you set this parameter to a value greater than 123, the system will simply substitute a value of 123.

Like parameters #13 and #15, larger values can result in larger (more efficient) packets, at the expense of greater latency. Also, at higher baud rates, setting this value too high can result in dropped characters.

ID 15 **– Inter-characeter Timeout** - tune inter-character serial data timeout

This value is in milliseconds, and defaults to 0 (in other words, disabled).

This timeout is similar to NV Parameter #13, but this one refers to the time *between* individual characters. One way of thinking of it: this timeout restarts with every received character - the other timeout always runs to completion.

Larger inter-character timeouts can give better MULTICAST TRANSPARENT MODE reliability, at the expense of greater latency.

Note that either timeout #13 or #15 (if enabled) can trigger the transmission of the buffered data.

Note that any of these three parameters (ID #13-15) can serve as the trigger for transmission of the buffered serial data.

ID 16 – **Carrier Sense** – basically "listen before you transmit"

This value defaults to False. Setting this value to True will cause the node to do what is called a Clear Channel Assessment (CCA). Basically this means that the node will briefly listen before transmitting anything, and will postpone sending the packet if some other node is already talking. This results in fewer collisions (which means more multicast packets make it through), but the "listening" step adds about 370 microseconds to the time it takes to send each packet.

If in your network the probability of collisions is low (you don't have much traffic), and you need the maximum throughput possible, then leave this value at its default setting of False. If in your network the probability of collisions is high (you have a lot of nodes talking a lot of the time), then you can try setting this parameter to True, and see if it helps your particular application.

ID 17 – **Collision Detect** – basically "listen after you transmit"

This value defaults to False. Setting this value to True will cause the node to do a CCA after sending a multicast packet. This will catch some (but not all) collisions. If the node detects that some other node was transmitting at the same time, then it will resend the multicast packet. This results in more multicast packets making it through, but again at a throughput penalty.

The same criteria given for NV Parameter #16 apply to this one as well. You can try setting this parameter to True, and see if it helps your application. If not, set it back to False.

ID 18 – **Collision Avoidance** – Control use of "random jitter" to try and reduce collisions

This setting defaults to True.

The SNAP protocol uses a "random jitter" technique to reduce the number of collisions.

Before transmitting a packet, SNAP does a small random delay. This random delay reduces the number of collisions, but increases packet latency

If you set this parameter to False, then this initial delay will not be used. This reduces latency (some extremely time critical applications need this option) but increases the chances of an over-the-air collision.

You should only change this parameter from its default setting of True if there is something else about your application that reduces the chances of collision. For example, some applications operate in a "command/response" fashion, where only one node at a time will be trying to respond anyway.

ID 19 **– Radio Unicast Retries –** Control number of unicast transmit attempts.

This parameter defaults to 8. This was the previously hard-coded value.

This parameter refers to the total number of attempts that will be made to get an acknowledgement back on a unicast transmission to another node.

In some applications, there are time constraints on the "useful lifetime" of a packet. In other words, if the packet has not been successfully transferred by a certain point in time, it is no longer useful. In these situations, the extra retries are not helpful – the application will have already "given up" by the time the packet finally gets through.

By lowering this value from its default value of 8, you can tell SNAP to "give up" sooner.

A value of 0 is treated the same as a value of 1 – a packet gets <u>at least one chance</u> to be delivered no matter what

ID 20 **– Mesh Routing Maximum Timeout –** the maximum time (in milliseconds) a route can "live"

Discovered mesh routes timeout after a configurable period of inactivity (see #23), but this timeout sets an upper limit on how long a route will be used, even if it is being used heavily. By forcing routes to be rediscovered periodically, the nodes will use the shortest routes possible.

Note that you *can* set this timeout to zero (which will disable it) if you know for certain that your nodes are stationary, or have some other reason for needing to avoid periodic route re-discovery.

ID 21 **– Mesh Routing Minimum Timeout –** the minimum time (in milliseconds) a route will be kept.

ID 22 **– Mesh Routing New Timeout –** a grace period (in milliseconds) that a newly discovered route will be kept, even if it is never actually used.

ID 23 **– Mesh Routing Used Timeout –** how many additional milliseconds of "life" a route gets whenever it is used.

Every time a known route gets used, it's timeout gets reset to this parameter. This prevents active routes from timing out as often, but allows inactive routes to go away sooner. See also parameter #20, which takes precedence over this timeout.

ID 24 **– Mesh Routing Delete Timeout –** this timeout (in milliseconds) controls how long "expired" routes are kept around for book-keeping purposes.

ID 25 - **Mesh Routing RREQ Retries –** this parameter controls the total number of retries that will be made when attempting to "discover" a route (a multi-hop path) over the mesh.

ID 26 **– Mesh Routing RREQ Wait Time –** this parameter (in milliseconds) controls how long a node will wait for a response to a **Route Request (RREQ)** before trying again.

Not that subsequent retries use longer and longer timeouts (the timeout is doubled each time). This allows nodes from further and further away time to respond to the RREQ packet.

ID 27 **- Mesh Routing Initial Hop Limit –** this parameter controls how far the initial "discovery broadcast" message is propagated across the mesh.

If your nodes are geographically distributed such that they are always more than 1 hop away from their logical peers, then you can increase this parameter. Consequently, if most of your nodes are within direct radio range of each other, having this parameter at the default setting of 1 will use less radio bandwidth.

*This parameter should remain less than or equal to the next parameter, **Mesh Routing Maximum Hop Limit**.*

Also, although Portal (or Gateway) are "one hop further away" than all other SNAP nodes on your network (they are on the other side of a "bridge" node), the SNAP code knows this, and will automatically give a "bonus hop" to this parameter's value when using it to find nodes with addresses in the reserved Portal/Gateway address range of 00.00.01 – 00.00.15. So, you can leave this parameter at its default setting of 1 (one hop) even if you use Portals and/or Gateways.

ID 28 - **Mesh Routing Maximum Hop Limit –** to cut down on needless broadcast traffic during mesh networking operation (thus saving both power and bandwidth), you can choose to lower this value to the maximum number of physical hops across your network.

ID 29 **- Mesh Sequence Number - reserved for future use**.

ID 30 - **Mesh Override** is used to limit a nodes level of participation within the mesh network.

When set to the default value of 0, the node will fully participate in the mesh networking. These means that not only will it make use of mesh routing, but it will also "volunteer" to route packets for other nodes.

Setting this value to 1 will cause the node to stop volunteering to route packets for other nodes. It will still freely use the entire mesh for its own purposes.

This feature was added to better supports nodes that spend most of their time "sleeping". If a node is going to be going to be asleep, there is no point in it becoming part of routes *for other nodes* while it is (briefly) awake.

This can also be useful if some nodes are externally powered, while others are battery powered. Assuming sufficient radio coverage (all the externally powered nodes can "hear" all of the other nodes), then the **Mesh Override** can be set to 1 in the battery powered nodes, extending their battery life at the expense of reducing the "redundancy" in the overall mesh network.

ID 31 **– Mesh Routing LQ Threshold –** allows penalizing hops with poor Link Quality

Until version 2.1, there was no way to take Link Quality into account when choosing the best mesh route to use. Now, advanced users can set a threshold value.

Hops that have a link quality worse than (ie a higher value than) the specified threshold will be counted as two hops instead of one.

This allows the nodes to choose (for example) a two-hop route with good link quality over a one-hop route with poor link quality.

The default threshold setting is such that no "one hop penalty" will ever be applied.
See also new NV Parameter #39.
ID 32 through 38 **– reserved for future Synapse use.**

ID 39 **– Radio LQ Threshold –** allows ignoring packets with poor Link Quality

Link Quality values range from a theoretical 0 (perfect signal, 0 attenuation) to a theoretical 127 (127 dBm "down"). I say theoretical because the radio we use will never report values at these extremes.

This parameter defaults to a value of 127, which makes it have no effect (you cannot receive a packet with a Link Quality "worse" than 127).

If you lower this parameter from its default value of 127, you are in effect defining an "acceptance criteria" on all received packets. If a packet comes in with a Link quality worse (higher) than the specified threshold, then the packet will be completely ignored.

This gives you the option to ignore other nodes that are "on the edge" of radio range. The idea is that you want other (closer) nodes to take care of communicating to that node.

Caution **–** if you set this parameter too low, your node may not accept any packets.

ID 40 – **SNAPpy CRC** – the 16-bit Cyclic Redundancy check (CRC) of the currently loaded SNAPpy script.

Most users will not need to write to this NV Parameter. If you *do* change it from its automatically calculated value, you will make the SNAP node think its copy of the SNAPpy script is invalid, and it will not use it.

ID 41 through 49 – **reserved for future Synapse use.**

ID 50 – **Enable AES-128** – control AES-128 Encryption (in firmware that supports it)

This value defaults to False (encryption off).

Even if set to True, encryption won't take place unless an encryption key has also been provided.

ID 51 – **AES-128 Key** – specify the 128-bit encryption key

This NV Parameter is a string with default value of ""

An encryption key must be exactly 16 bytes (128 bits) long to be valid.

This parameter has no effect unless NV Parameter #50 is also True.

Even if both parameters 50 and 51 are set correctly, they will have no effect unless they are used in conjunction with a SNAP firmware image that supports AES-128 encryption.

Firmware images supporting AES-128 encryption will have "AES" in their filenames.

Refer also to function getInfo() in the SNAPpy API section.

ID 52 through 127 – **reserved for future Synapse use.**

ID 128 – 254 – these are user defined NV Parameters, and can be used for whatever purpose you choose.

ID 255 – **reserved for internal use** (0xFF means "blank" inside the actual NV storage)

10. Example SNAPpy Scripts

Example Scripts

The fastest way to get familiar with the SNAPpy scripting language is to see it in use. Portal comes with several example scripts pre-installed in the snappyImages directory.

Here is a list of the scripts preinstalled with Portal 2.1, along with a short description of what each script does. Take a look at these to get ideas for your own custom scripts. You can also copy these scripts, and use them as starting points.

Script Name	**What it does**
evalBase.py	An importable script that adds a library of helpful routines for use with the Synapse evaluation boards. Board detection, GPIO programming, and relay control are just a few examples
pinWakeup.py	An importable script that adds “wake up on pin change” functionality
switchboard.py	An importable script that defines some switchboard related constants (for readability)
PWM.py	An importable script that adds support for Pulse Width Modulation (PWM) on pin GPIO 0
ledCycling.py	An example of using PWM.py. Varies the brightness of the LED on the Demonstration Boards
servoControl.py	A second example of using PWM.py. Controls the position of a standard hobby servo motor
McastCounter.py	Maintains and displays a two-digit count, incremented by button presses. Resets the count when the button is held down. Broadcasts “count changes” to any listening units, and also acts on “count changes” from other units.
DarkDetector.py	Monitors a photocell via an analog input, and displays a “percent darkness” value on the seven-segment display. Also requests a short beep *from a node running the buzzer.py script* when a threshold value is crossed.
buzzer.py	Generates a short beep when the button is pressed. Also provides a “buzzer service” to other nodes. The example script DarkDetector.py shows one example of using this script.
protoSleepcaster.py	Like McastCounter.py but this script is only for the SN171 Proto Board, plus it goes to sleep between button presses
protoFlasher.py	Just blinks some LEDs
lunarLander.py	A script that implements a numeric form of the classic Lunar Lander game. Note that this example requires four nodes with seven segment displays.

LinkQualityRanger.py	Radio range testing helper
ledToggle.py	Simple example of toggling an LED based on a switch input
gpsNmea.py	Example decoding of data from a serial GPS
EvalHeartBeat.py	Example of displaying multiple networking parameters about a node on a single seven-segment display
DarkroomTimer.py	Operates a dark room enlarger light under user control
CommandLine.py	An example of implementing a command line on serial port 1. Provides commands for LED, relay, and seven-segment display control
datamode.py	An example of using two nodes to replace a RS-232 serial cable
dataModeNV.py	A more sophisticated example of implementing a wireless UART

Here is a second table listing the included scripts, this time organizing them by the techniques they demonstrate. This should make it easier to know which scripts to look at first.

Technique	**Example scripts that demonstrate this technique**
Importing evalBase.py and using the helper functions within it	CommandLine.py DarkDetector.py DarkRoomTimer.py EvalHeartBeat.py gpsNmea.py ledToggle.py LinkQualityRanger.py lunarLander.py McastCounter.py protoSleepCaster.py
Performing actions at startup, including using the setHook() function to associate a user defined function with the HOOK_STARTUP event	CommandLine.py DarkDetector.py DarkRoomTimer.py EvalHeartBeat.py gpsNmea.py ledToggle.py LinkQualityRanger.py lunarLander.py McastCounter.py protoFlasher.py protoSleepCaster
Performing actions when a button is pressed, including the use of monitorPin() to enable the generation of HOOK_GPIN events, and the use of setHook() to associate a user defined routine with those events	buzzer.py DarkRoomTimer.py gpsNmea.py ledToggle.py lunarLander.py McastCounter.py protoSleepCaster.py
Sending multicast commands	LinkQualityRanger.py lunarLander.py McastCounter.py protoSleepCaster.py
Sending unicast commands	DarkDetector.py

Using global variables to maintain state between events	DarkDetector.py DarkRoomTimer.py EvalHeartBeat.py gpsNmea.py ledToggle.py LinkQualityRanger.py lunarLander.py McastCounter.py protoFlasher.py protoSleepCaster.py
Controlling a GPIO pin using writePin(), etc.	buzzer.py evalBase.py gpsNmea.py ledToggle.py protoFlasher.py protoSleepCaster.py
Generating a short pulse using pulsePin()	buzzer.py
Reading an analog input using readAdc(), including auto-ranging at run-time	DarkDetector.py lunarLander.py
Performing periodic actions, including the use of setHook() to associate a user defined routine with the HOOK_100MS event	buzzer.py DarkDetector.py DarkRoomTimer.py EvalHeartBeat.py gpsNmea.py LinkQualityRanger.py lunarLander.py McastCounter.py protoFlasher.py protoSleepCaster.py
Using the seven-segment display	DarkRoomTimer.py evalBase.py EvalHeartBeat.py LinkQualityRanger.py lunarLander.py McastCounter.py
Deriving longer time intervals from the 100 millisecond event	buzzer.py DarkRoomTimer.py EvalHeartBeat.py McastCounter.py
Thresholding, including periodic sampling and changing the threshold at run-time	DarkDetector.py
Discovering another node with a needed capability	DarkDetector.py
Advertising a service to other wireless nodes	buzzer.py
Adding new capabilities by writing directly to processor registers (peek() and poke())	pinWakeup.py PWM.py

Writing parameters to Non-volatile (NV) storage	evalBase.py
The use of “device types” as generic addresses, or to make a single script behave differently on different nodes	buzzer.py DarkDetector.py evalBase.py lunarLander.py
Sleeping and waking up on a button press, importing and using pinWakeup.py	protoSleepCaster.py
Knowing when a RPC call has been sent out, by using HOOK_RPC_SENT.	protoSleepCaster.py
Distributing a single application across multiple nodes	lunarLander.py
Monitoring link quality using the getLq() function	LinkQualityRanger.py
Parsing received serial data in a SNAPpy script (contrast with Transparent Mode)	CommandLine.py gpsNmea.py
Displaying hexadecimal data on the seven-segment display	EvalHeartBeat.py
Displaying custom characters on the seven-segment display	DarkRoomTimer.py EvalHeartBeat.py
Configuring Transparent Mode AKA Data Mode	datamode.py dataModeNV.py
Varying LED brightness using Pulse Width Modulation	ledCycling.py
Controlling a servo motor using Pulse Width Modulation	servoControl.py

11. Portal API

This section details the API presented to Portal Scripts. The ***Command Line*** window of Portal also has access to this API.

Node Methods

The following are functions bound to each Network Device (Node) known to Portal, i.e. visible in one of the **Node Views**, or appearing in the **Node Info** window.

To invoke one of these methods, you must prefix the desired function name with the name of the node that you want to invoke the function on, followed by a "." character. For example:

McastCounter.reboot()

getColumn(*name*)	Returns the current value stored for the specified column name
getFormatedNetAddr()	See next function - This was mis-spelled in the previous release, and the mis-spelling has been maintained for backwards compatibility. New scripts should use function getFormattedNetAddr() instead
getFormattedNetAddr()	Returns this node's network address as a string in the format ##.##.##
linkQualityAsk()	Queries the node for is currently link quality value
linkQualityPercentVal()	Returns an integer value in the range 0-100 based on the node's last queried link quality
macAsk()	Queries the node for it's MAC address
netParamAsk()	Queries the node for it's channel and network ID
ping(*toggleResponding*=True)	PING's the node. Parameter *toggleResponding* determines how the result of the PING affects the Node Views and Node Info windows
reboot()	Tells the node to reboot
refresh(*ping*=True, *toggleResponding*=True)	Queries the node for information to display in it's Node Info tab.
setColumn(*name*, *value*)	Stores the specified value for the specified name
setNvParam(*id*, *value*)	Tells the node to set the NV parameter *id* to the specified *value*.
setStdoutPortal()	Tells the node to redirect it's STDOUT to Portal's network address. Whatever the node prints will appear in the Portal Event Log
versionAsk()	Queries the node for it's current version string

Node Attributes

The following are attributes bound to each Network Device (Node) known to Portal, i.e. visible in one of the **Node Views**.

Like the node methods, these must be prefixed by the name of the node you want to examine, and a "." character. For example:

print McastCounter.channel

Also notice that these are data fields, not functions. Do not put parentheses "()" after them.

McastCounter.channel is a number
McastCounter.channel() is an error.

channel	An integer corresponding to the node's channel
isResponding	A boolean value corresponding to if the last query was successful
lqVal	A float value of the node's last queried link quality in dBm
name	A string that describes this node in Portal's node views
netAddr	A string containing this node's unformatted network address
networkId	An integer corresponding to the node's network id
version	A string containing the node's last queried version

Portal Methods

The following methods are independent of SNAP Nodes. They provide a system-level interface between Portal Scripts and system-wide capabilities.

Because they are not node specific, you do not prefix them with a node name and a "." character.

Some of these routines do take a *node* parameter. You can specify the correct node in two different ways:

1) By explicit address
2) By node name (the node's name within Portal)

Explicit addresses are three-byte strings. Portal shows node Network Addresses in hexadecimal, but omits any number base prefixes or suffixes. If Portal shows a node's Network Address as 12.34.56, then the individual address bytes are 0x12, 0x34, and 0x56 (hexadecimal), not 12, 34, and 56 (decimal).

To specify hexadecimal constants within Python or SNAPpy strings, you use a leading "\x". Going back to our example, if you want to specify the node with address 12.34.56, you would use "\x12\x34\x56" in your script.

Portal also assigns names to nodes when it first discovers them. If the node with address 12.34.56 has a displayed name of "McastCounter", then instead of specifying an explicit address string, you can just use the text McastCounter instead.

Notice that there are <u>no</u> quotation marks used when referencing nodes *by name* within Portal scripts (or from the Portal command line).

So, assuming node McastCounter4 is at address AB.CD.EF, the following two commands are equivalent:

sendData("\xAB\xCD\xEF", "This is a test")

sendData(McastCounter4, "This is a test")

logEvent(*message*)	Log the specified *message* to the Event Log
logData(*name*, *value*, *fullscale*=100.0)	Plot the specified *value* to a named strip chart in the Data Logger window
multicastRpc(*groups*, *ttl*, *function*, **args*)	Sends a multicast RPC request to the specified *groups*. Parameter *function* is what routine to invoke on each node in the specified *groups*, and the remaining parameters are passed to that routine.
rpc(*node*, *function*, **args*)	Sends an RPC request to the specified node. Parameter *function* is what routine to invoke on the node, and the remaining parameters are passed to that routine.
sendData(*node*, *data*)	Sends *data* to the specified *node* in a way that mimics TRANSPARENT MODE. This lets Portal insert data into TRANSPARENT MODE links.
sendEmail(*recipients*, *sender*, *msg*, *server*)	Sends an email containing *msg* text to the specified *recipients* via the specified (email) *server*, addressed as if it came from *sender*.

There are also some commands that must be prefixed by “root.” - This prefix is not shown in the following table, but for example “displayTraceFile” is really specified as “root.displayTraceFile()” in scripts or from the command line.

clearEventLog()	Clears the Portal Event Log
displayTraceFile()	Pops up a tabbed window with the contents of an internal log file sometimes used in debugging.
sendDataModePkt(*node*, *data*)	This is the same as the standalone function sendData(), use sendData() instead
setPortalNetAddr(*newAddr*)	Change Portal’s Network Address from the default value of “\x00\x00\x01” (00.00.01). You have to restart Portal for the change to actually take effect.

There are several commands that are deprecated or for Synapse internal use only. They are listed here only for completeness; you **should not** be calling these functions.

cmdDispatcher	Synapse use only
notifyOnComplete()	Synapse use only
setupSynapseUsb()	Synapse use only
snappyErrorDecode(*node*, *errorMsg*)	Synapse use only

12. SNAP Node Views

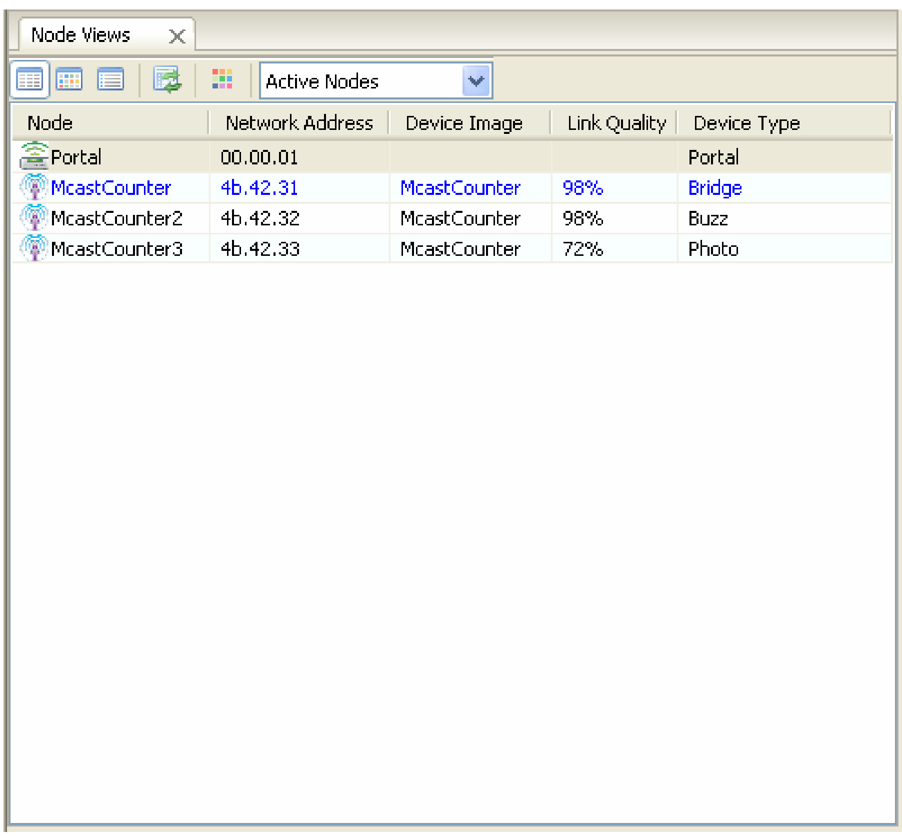
The starting point for managing SNAP nodes is the **Node Views** tabbed window. If this window is not already open, you can click on **View**, then choose **Node Views window**. Alternatively, you can click on the icon on the toolbar.

You will notice that the **Node Views** window has its own toolbar.

The **Node Views** tabbed window lets you look at your nodes in three different ways:

- **Report View**
- **Icon View**
- **List View**

All three views are just that, "views" of the same network information. Click on the **Change to Report View** button in the **Node Views** toolbar (not the main toolbar).



Several columns of information are shown about each node.

Node	Network Address	Device Image	Link Quality	Device Type
Portal	00.00.01			Portal
McastCounter	4b.42.31	McastCounter	98%	Bridge
McastCounter2	4b.42.32	McastCounter	98%	Buzz
McastCounter3	4b.42.33	McastCounter	72%	Photo

The **Node** column shows an *icon* and a *name* for each node. Both the icon and name can be changed by the user, what you see here are just the default icons.

 is used within Portal to generically represent any SNAP node.

 is used within the Portal user interface to represent Portal itself.

(Remember, Portal is able to participate in the network as if it were a wireless node.)

The name for the node is assigned when the node is first discovered, and can come from three possible sources:

- As of version 2.1, it is possible to assign a name to a node
- If you don't give a node a name, it will use the name of any loaded script
- If no name given and no script loaded, Portal will use "Node" as a base name

A trailing numeric identifier is sometimes appended to the base name, so that all nodes have unique names. This is a Portal requirement, you can rename your units but each name must be unique.

The **Network Address** column shows the three byte Network Address for each node. The Network Address is simply the last three bytes of the node's MAC Address, and is not user definable.

The **Device Image** column shows the SNAPpy script/image loaded into the device. If there is no script loaded into the node, then this field is blank. Notice that this field tracks the currently loaded script. If you upload a different script into a node *after* it has been discovered/named, then this column can be different from the **Node** column.

The **Link Quality** column shows a snapshot of the *radio* receive level. It is expressed as a percentage, with 0% representing the weakest possible signal and 99% representing a maximum strength signal.

It is important to understand three things about the displayed Link Quality:

1) Normally this field **is not** continuously refreshed - Portal does not "poll" nodes unless you tell it to. You *can* use the **Broadcast PING** button to update the Link quality fields of all active units. There is also a "refresh" button you can click on to force a refresh of a single node's Link Quality. This button is on the **Node Info** toolbar, and is covered in section 13. Finally, there is a **Watch Nodes** button that essentially turns on "automatic Broadcast Pings".

2) The value shown is based on the received signal strength of the most recent message *from **any** other wireless node*. It **does not** represent the signal strength between Portal and the node (it **is not** an indication of the USB or RS232 quality between Portal and Portal's "bridge" node).

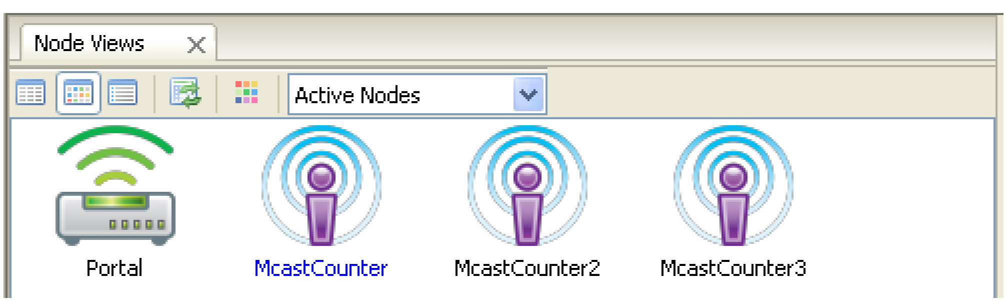
3) It is possible that *at the time* the **Link Quality** field was read from the unit, it had *not yet* received any radio messages from any other node. In this case, a value of 0 will be reported. This does not mean the unit has a faulty radio, it simply has not done any radio communications yet. This is most often seen with the node that is acting as a "bridge" for Portal, because Portal can be interacting with this *directly attached* node *without* necessarily generating any **radio** traffic.

The **Device Type** column shows one of the non-volatile (NV) configuration parameters of the unit. Device Type is simply a second string label that can be applied to a node. Unlike the **Node Name**, this label does not have to be unique, and is often used to show what job or role a node is filling. This parameter can also be read by SNAPpy scripts, allowing a single script to act differently on different nodes, simply by setting the Device Type of each node appropriately.

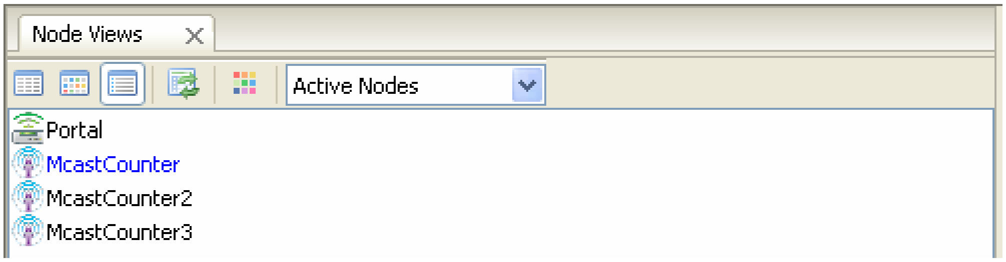
You may sometimes notice one of the nodes highlighted in blue. This is Portal's way of showing which node it thinks is its "bridge" onto the SNAP network.

NOTE – If you move cables around (etc.) it is possible to trick Portal. The blue highlighting is really only accurate when you first discover your SNAP network. (You can use **Network** -> **New Configuration…** to force a re-discovery.)

Clicking on the **Icon View** button brings up the following representation of your network.



In this view only the Node Icon and Node Name are shown.
Clicking on **List View** brings up the final alternate view of your network.



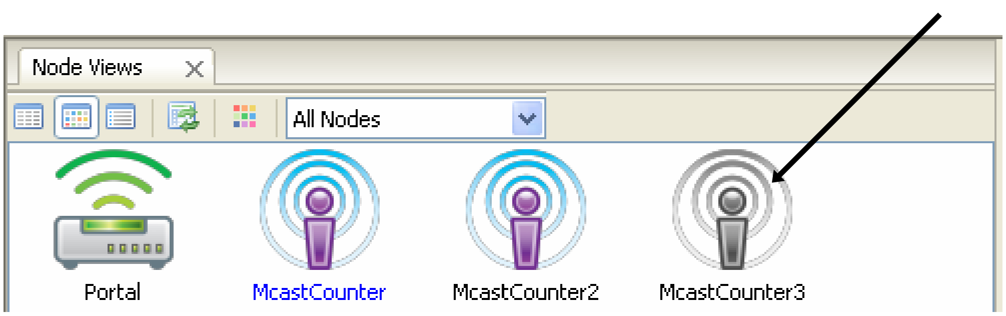
This view shows the same information as the **Icon View**, but comes in handy when you have a large quantity of SNAP nodes in your network.

The fourth tool-bar button **Watch Nodes** has already been mentioned briefly. This button toggles Portal's "Node Watcher" (automatic periodic polling of nodes). If you need to "see" nodes coming and going, you can turn on the Node Watcher instead of manually hitting **Broadcast PING** periodically.

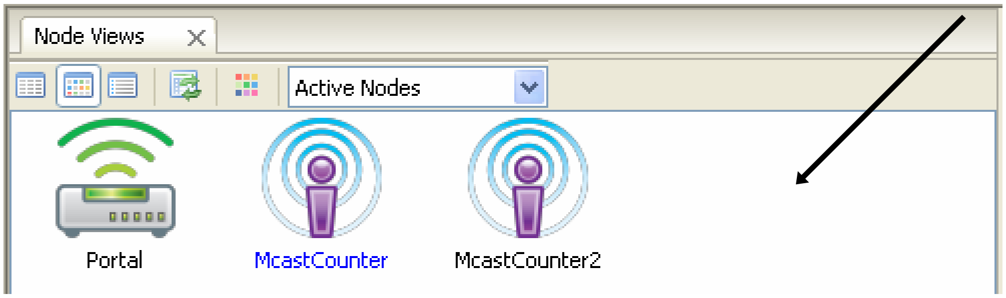
The fifth tool-bar button brings up a color selection dialog, and can be used to change the background color of these views. You might need to do this if you are using your own custom icons.

The last control in the Node Views toolbar is a drop-down selector box that lets you choose to see only the **Active Nodes** or **All Nodes**. Both views are identical as long as all nodes are online and communicating.

With the filter set to show **All Nodes**, if a unit has stopped responding to Portal, it will be greyed-out in all three views.



With the filter set to show only **Active Nodes**, if a unit has stopped responding to Portal it will be completely removed from all three views.



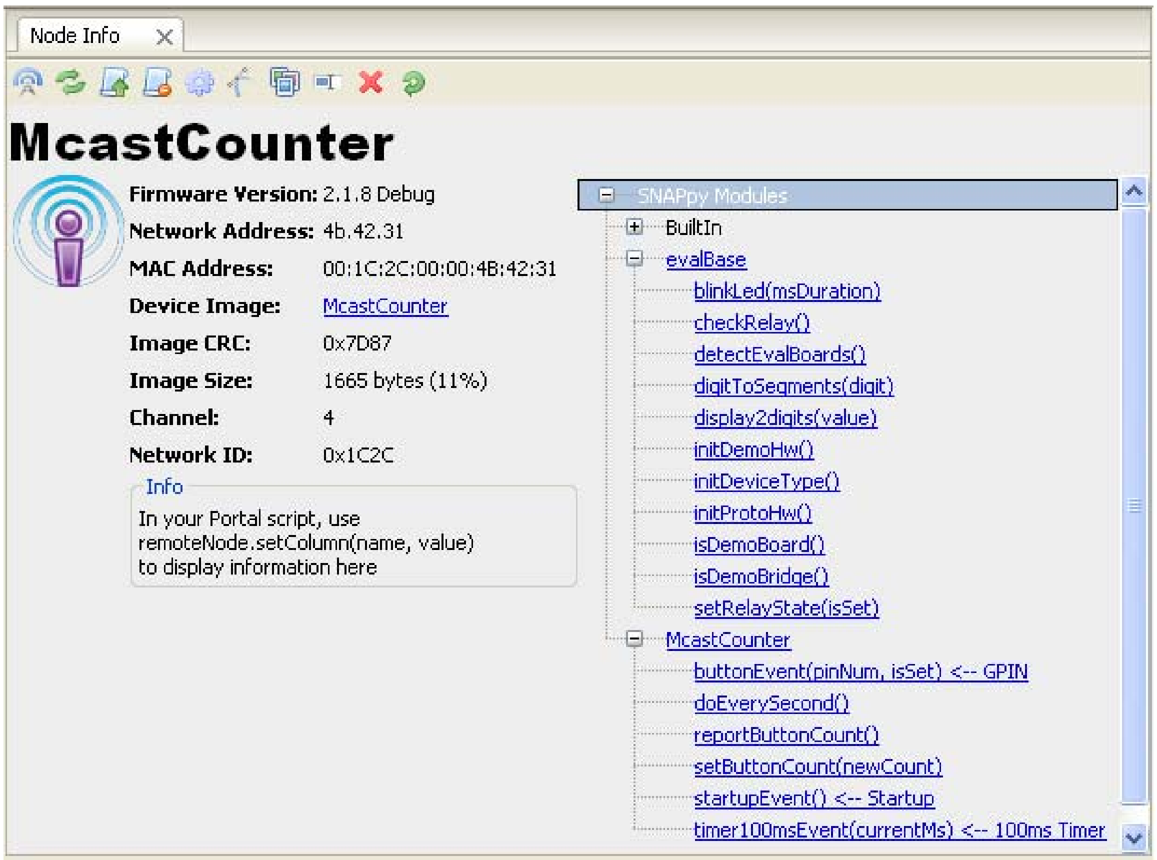
Screenshots are only shown for the **Icon View**, but the other views behave similarly.

13. SNAP Node Configuration

The configuration of an individual Node can be viewed and changed from the **Node Info** tab. *Which* node to display info about is controlled from the **Node Views** tabbed window.

If the **Node Info** tab is already visible within Portal, a single-click on a Node in one of the other tabs will display that specific node's info in the **Node Info** tab.

If the **Node Info** tab is not already visible, a double-click on the desired node will be required to bring up the **Node Info** tab.



Starting in the upper left-hand corner, the **Node Info** tab shows the:

- "logical name" of the node
- Firmware version and type if special
- Some Network Configuration parameters
- Device Image and Image CRC
- Some more Network Configuration parameters

The left-hand side continues with an **Info** pane. The right-hand side shows a tree view of the callable scripted functions.

Network Configuration Parameters

There are four network configuration parameters: **Network Address**, **MAC Address**, **Channel**, and **Network Identifier (ID)**.

SNAP MAC addresses are standard 64-bit IEEE MAC addresses, as required by the 802.15.4 specification. MAC addresses are assigned to the node at the factory.

The **Network Address** is the three byte identifier that is actually used "over the air" by the SNAP wireless protocol. You will notice that it matches the *last three bytes* of the eight byte MAC Address.

Channel - There are 16 allotted channels in the 2.4GHz band used by 802.15.4. Officially numbered channels 11-26 by 802.15.4, they are designated channels 0-15 by Synapse products.

The SNAP **Network ID** can be thought of as a "logical channel". This 16-bit integer may be assigned any hexadecimal value from 0x0001 through 0xFFFE. Devices in a SNAP network must share both the same Channel and same Network ID in order to communicate. This allows multiple SNAP networks to share the same channel if required, although it is preferred to place independent networks on separate *physical* channels to reduce collisions.

Node Info - Tasks Pane

There are ten toolbar options in this pane:

- **Ping** - poll a unit for connectivity
- **Refresh** - poll a unit for the values shown in the Node Info tab
- **Upload SNAPpy Image** - program a node with a new script
- **Erase SNAPpy Image** - remove previously loaded script
- **Change Configuration Parameters** - more on this below
- **Intercept STDOUT** - divert the node's script output to Portal
- **Change Icon** - substitute an alternate PNG file as the node's icon
- **Rename Node** - replace the current node name
- **Remove Node** - remove the node from the various **Node Views**
- **Reboot Node** – reboot the node

Ping

Clicking on this action causes Portal to make a quick connectivity test to the current node. Observe the Event Log for confirmation of Ping activity.

A **Broadcast Ping** command (seen by all nodes) is also available in the Portal toolbar, here:

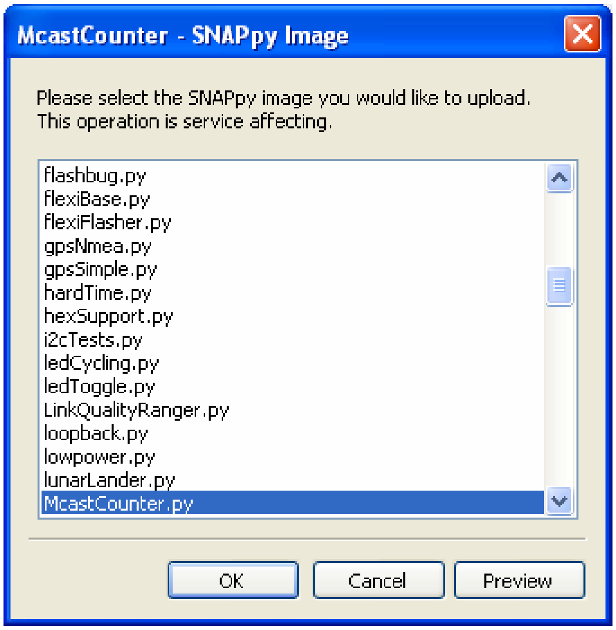
⇩

Refresh

Observe the Event Log for confirmation of Refresh activity.
Clicking on this action will poll the node for the information shown in the upper left corner of the **Node Info** tab.

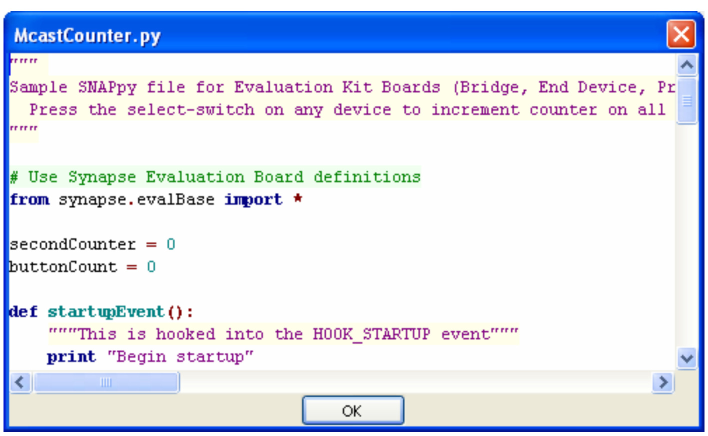
Upload Snappy Image

Clicking on this action will bring up a dialog box allowing you to choose which script to upload into the unit.

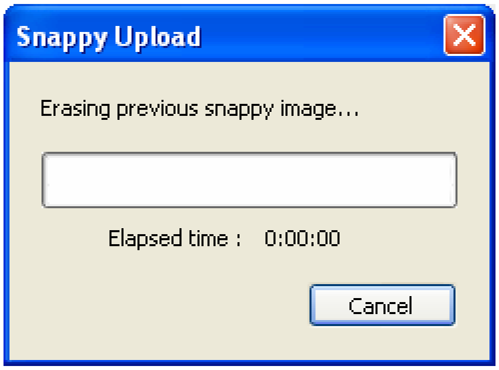


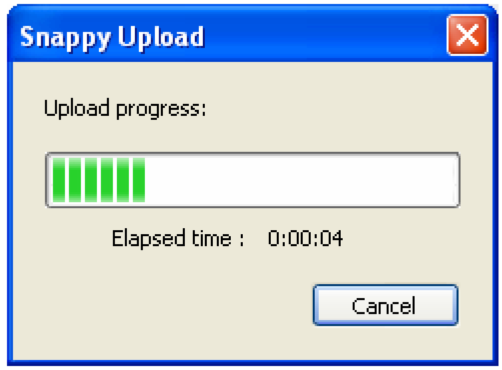
A node can only contain one script at a time, but the script can actually consist of multiple source files, using the Python "import" functionality.

If you are not sure which script you want, you can click on the **Preview** button to take a quick look at the currently selected script. Click **OK** when you are done looking at it.



Once the “root” script has been chosen, Portal will tell the node to erase any previous script, and then upload the new script to the Node.





Once the entire script has been uploaded to the node, Portal will automatically reboot the node, which in turn will cause the node to execute any script code contained within the HOOK_STARTUP event handler of that script.

SNAPpy scripting is discussed in section 5.

Erase Snappy Image

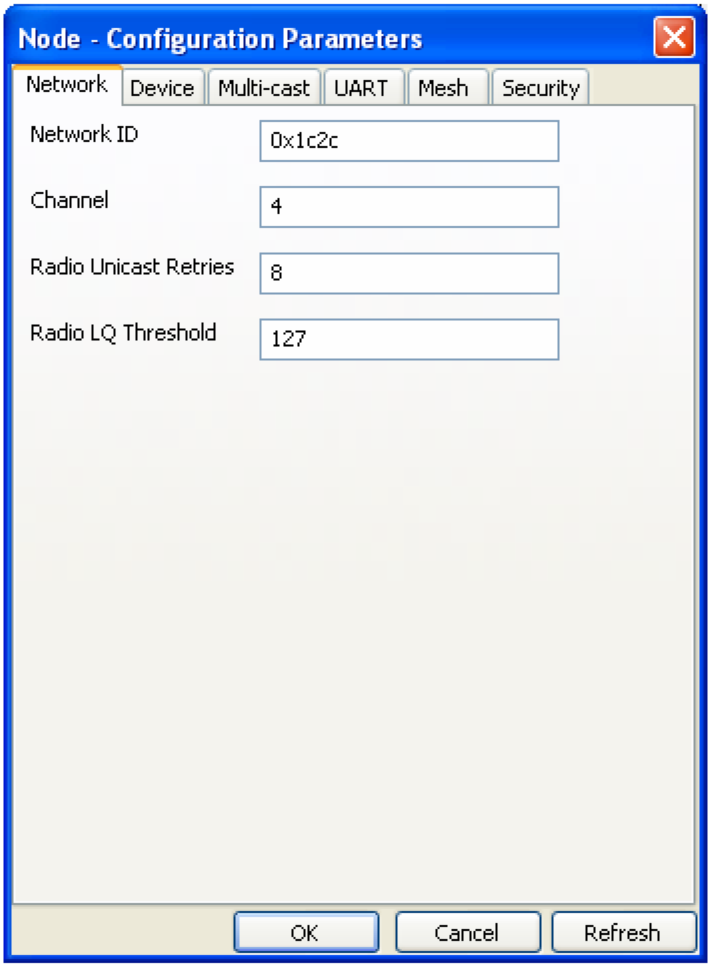
Clicking on this action will erase any currently loaded (and running) script from the selected node.

NOTE – You do not have to manually erase a previous script to load a new one, Portal will do this for you. This button has been added so that mis-behaving scripts can be shut down, while you work on making corrections to them.

If you click on the name of a script within the **Node Info** window, an editor window containing that script will be opened for you.

Change Configuration

Clicking on this task will bring up the following (tabbed) dialog box:



From this dialog box, you can view and edit the Configuration Parameters of the current SNAP Node.

Configuration Parameters are also known as NV Parameters, and they are all described in section 9.

You can see the different NV Parameters broken down by category by clicking on one of the six named tabs within the dialog box.

The **Network** tab lists parameters relating to general radio operations.

The **Device** tab lists parameters relating to node "identity", and some hardware features.

The **Multi-cast** tab lists parameters relating to multicast communications.
The **UART** tab lists parameters relating to the buffering of data received from either of the two system UARTs.

The **Mesh** tab lists parameters relating to the Mesh Routing capabilities of the node.

Synapse nodes communicate with each other using Mesh Routing. Basically this means that any unit can talk to any other unit (they are all *logical* peers within the mesh), even though in some cases units that are out of radio range of each other might have to talk “through” intermediate nodes to do so. Only units that are within radio range of each other can communicate directly (*physical* peers).

The necessary “route discovery” and “packet forwarding” necessary to make this work are all done automatically by the node.

There are several **Mesh Routing Timeouts**. The default values should cover most network topologies. Be careful if changing these values on remote nodes – you could make it impossible to communicate with the node remotely.

Contact Synapse Customer Support for assistance with tuning these timeout parameters.

There are also several “non-timeout” parameters:

The **Security** tab lists parameters relating to AES-128 encryption.

> Note that not all nodes support AES-128 encryption, this is a function of the SNAP firmware currently loaded into the node.

To change one or more of the editable fields, just type the replacement value(s) in before clicking on OK.

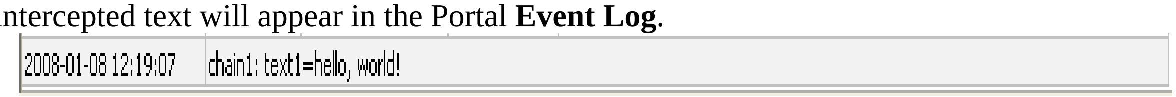
Intercept STDOUT

Script output (from “print” statements) normally goes to the “data sink” specified by the script itself. For example, the script might be outputting text to serial port 2.

For testing purposes, it is sometimes handy to “intercept” the script output from the node (which might be remotely located), and display it within Portal instead.

Clicking on this action will send the necessary commands to the node to accomplish this.

The intercepted text will appear in the Portal **Event Log**.



In the above example, the script did a **print “text1=hello, world”**. The node name (“chain1”) was pre-pended by Portal, providing an easy way to see which node the text came from.

Change Icon

You can replace the default icon Portal uses to represent each node with your own 60x60 PNG files. This might be used to make it easier to track which nodes are serving what purpose.

Rename Node

The default “logical name” for a node with no name provided by the user, and no scripts loaded is “Node” (for the first one found) or “NodeX” (for subsequent nodes), where “X” is a number (starting at 2) that represents the order in which Portal discovered the nodes.

Once a script has been uploaded into a Node, the default name becomes “*scriptname*” (for the first node found) or “*scriptname*X” (for subsequent nodes), but this new default will not override a name already assigned by Portal.

The Rename Node action allows you to choose your own name for a node, instead of using the default name assigned by Portal. Starting with version 2.1, this “given name” is stored in the node itself, and will automatically be re-used by Portal (instead of “Node” or the “*scriptname*”) if Portal re-discovers the node in the future.

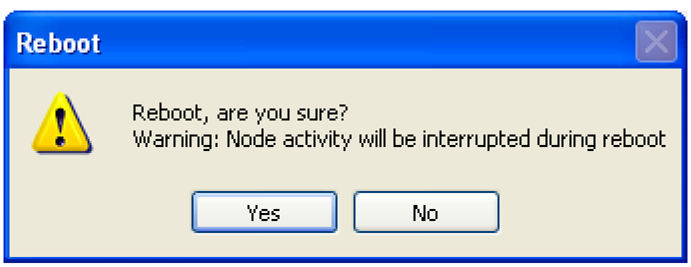
Remove Node

Clicking on this action will remove the node from Portal, including removing the node from the **Node Views**.

However, be aware that if the node really does still exist, it will simply be re-discovered by Portal on the next broadcast ping.

Reboot Node

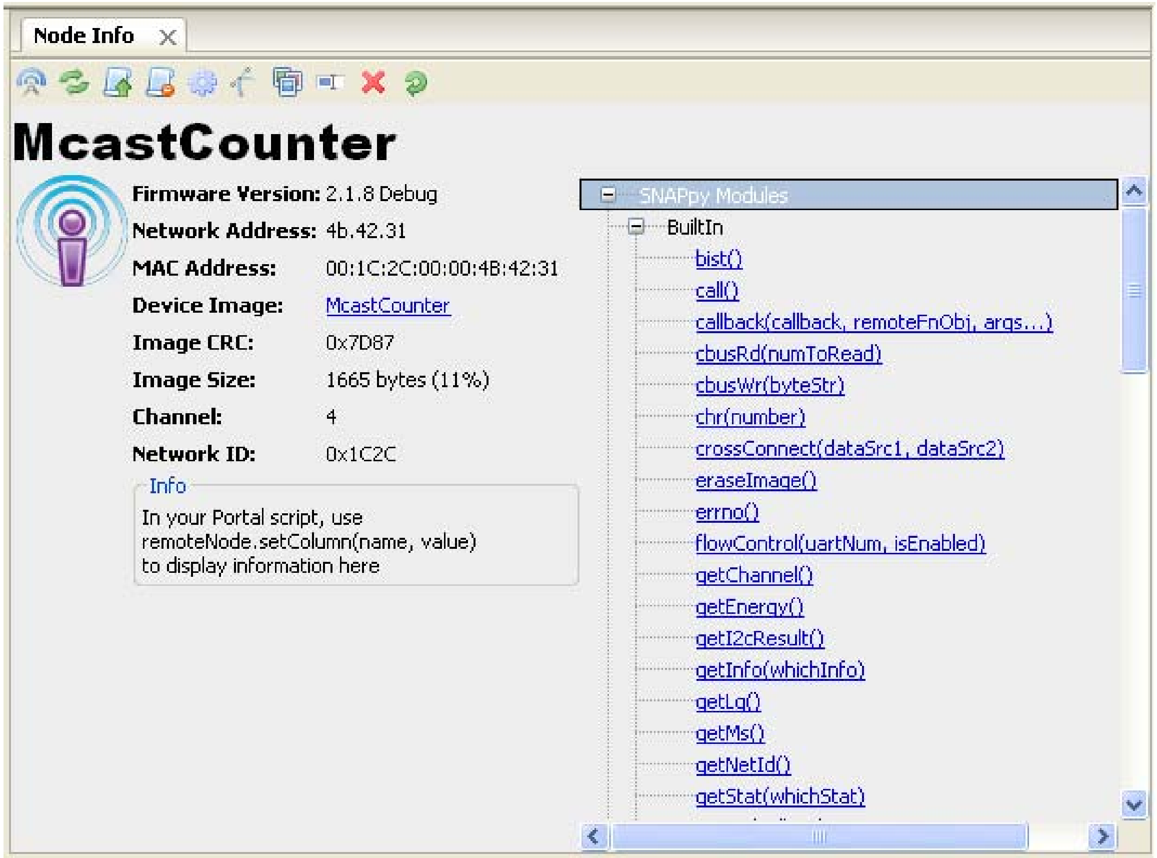
Clicking on this action will bring up the following prompt.



If you really do want to reboot (restart) the node, press **Yes**, otherwise press **No**.

Node Info – "Snappy Scripts" Section

The right hand side of the **Node Info** tab shows a tree view of all the callable functions within that node.



The **BuiltIn** functions represent the core SNAPpy feature set, and are functions that can be called *even when no user script has been uploaded* into the node. These same functions are also always available for use *within* scripts.

Refer to section 7 for details on these built-in SNAPpy functions.

The second branch of the tree view shows the name of the uploaded script's name, and underneath shows all of the callable functions implemented *by* that script.

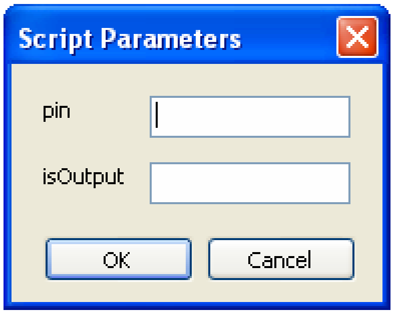
Hovering the mouse cursor over the links in either branch of the tree will bring up a short tool-tip on that function.

NOTE – for this to be useful for the functions defined in *your* scripts, be sure to put a Python "doc string" as the second line of your function definitions. For example:

```
def mySuperFunction():
   '''This is the text that will appear as a tool-tip'''
```

Clicking on any function name will remotely execute that function.

If the function takes parameters, a dialog box will pop up and prompt the user for the needed values.



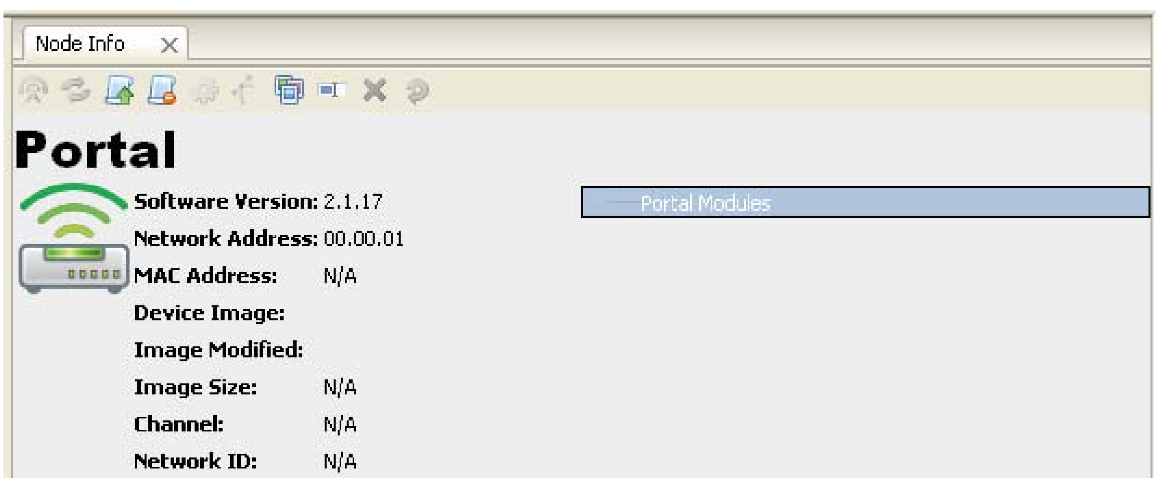
In the above example, clicking on the setPinDir() function has brought up a dialog box asking for "pin" (which GPIO pin, 0-18), and for a Boolean (True or False) value to make the pin be an input (False) or an output (True).

Once the values are filled in by the user, click on the OK button to invoke the function *on the actual node*.

This can be very useful for learning the built-in functions, as well as testing and debugging scripts.

Portal is a Node Too

Most of this section has been focused on using Portal to interact with remote SNAP nodes. However, Portal itself can function as a node on the network, and if you click on Portal in the **Node Views** pane, the **Node Info** pane will show info similar to the following.



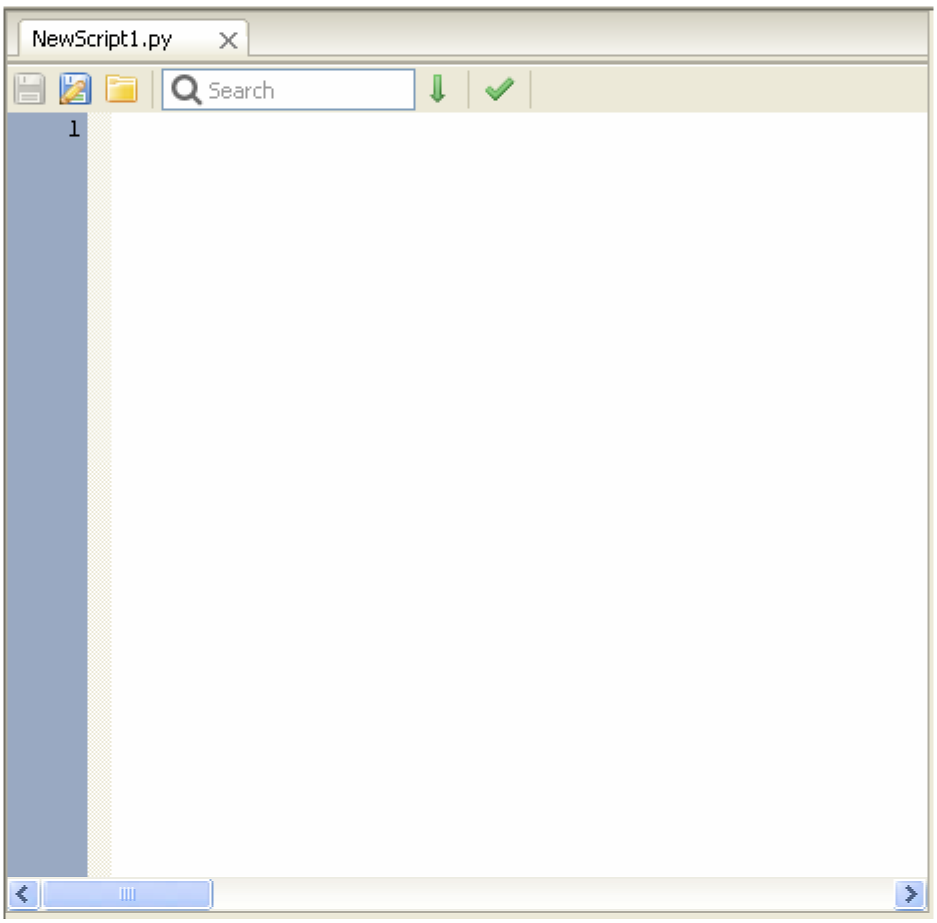
If a Portal script has been loaded, you will see it in the **Portal Modules** function tree as well. You can invoke any functions defined in that script by clicking on them, just like you can with the functions defined in the remote SNAP nodes.

14. Portal Tools

The main toolbar provides quick access to Portal's tabbed windows. These windows can be enabled, disabled, or rearranged to suit a variety of operational modes. Some of the toolbar buttons invoke immediate commands instead of opening new tabbed windows.

New Script

Clicking on this button will open a new **Edit Window** containing a new (empty) source file.

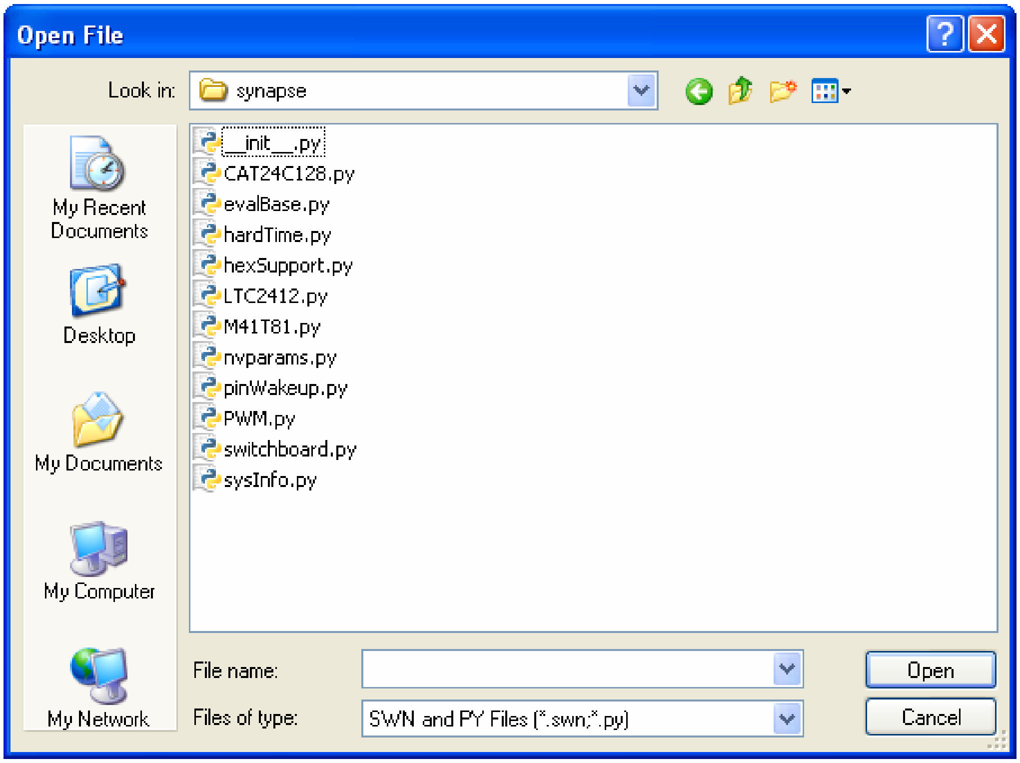


The default name of the script will be "NewScriptX" where "X" is a trailing number to enforce uniqueness.

The **Edit Window** is described in section 15.

Open File

Clicking on this button will bring up a file chooser dialog, from which you can select a previously saved source or Portal configuration file.



Source (.py) files can be SNAPpy scripts (these go into your SNAP nodes) or full Python files (these can be loaded into your Portal).

A Portal configuration specifies things like which Python script is currently loaded as the Portal Base File. Portal configurations are saved in files having a .SWN extension (Synapse Wireless Network), and are created using this next toolbar button.

Save All

This toolbar button will initiate creation of a .SWN file containing all of the currently active Portal settings. The most recently saved configuration file will automatically be re-loaded by Portal when it restarts.

Connect Serial Port / Disconnect Serial Port

This modal toolbar button is used to connect and disconnect from the attached bridge node. Because the icon and tool-tip changes when you connect or disconnect, it also serves as a quick status indicator.

If your nodes do not seem to be responding, this is the first item to check.

Broadcast Ping

Clicking on this toolbar button will cause Portal to broadcast a special “answer if you hear me” message to all nodes. When the nodes answer, any nodes that Portal did not already know about will be individually queried for additional information.

You might use this button if you just added one or more new nodes to your network.

Node Views

This tab provides a graphical display of the nodes in Portal’s internal device database. Internally, Portal indexes all nodes by network address. When a new network address is discovered, a corresponding icon in the Node Map will be created.

Deleting a Node (click on the Node and then select ***Remove Node*** from the Node Info tab) removes the Device from Portal’s internal database. This removes all knowledge of the Device from Portal. If the Device is subsequently re-discovered, usually via a ping, it will reappear in the Node Map.

The **Node Views** pane is covered in section 12.

Node Info

The Node Info tab provides node information, a mini-toolbar for common tasks, and SNAPpy script information about the currently selected node. (Refer to section 13).

Event Log

The Event Log captures real-time event history for Portal. All network-affecting activity is recorded here. Log entries are time-stamped to a 1-second resolution.

Events Captured Include:
Configuration save/load
Script STDOUT (print statements, errors)
Status messages
RPC communication messages

Command Line

The Command Line window provides interactive access to Portal’s Python based scripting engine. Using this tool, you can invoke the Device API on all discovered and active devices. This is useful for testing and debugging commands interactively before incorporating them into Portal scripts.

Most of what can be done through the command line can also be done through the other parts of the GUI. For example, you can type the command:

rpc(‘KB1’, ‘reboot’)

…***or*** you can just click on the reboot() function in the **Node Info** tree.

Within the **Command Line** pane, you can use the up and down cursor arrows to re-select previously executed commands. Position the cursor on a previously executed command, and it will be re-displayed (but not executed yet) at the bottom of the **Command Line** window. You can then edit the recalled command (use the left and right cursor keys to move the cursor horizontally within the command). When the command line has been edited to your liking, press the ENTER key to execute it.

To re-execute the most recently executed command *as-is* (no changes), just press the keys UP, ENTER, ENTER.

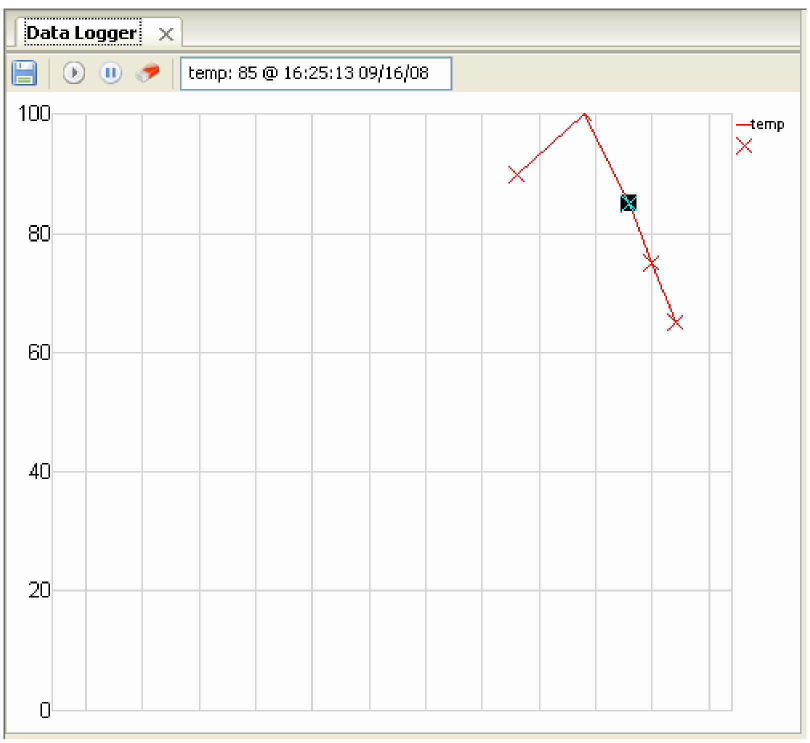
Within the **Command Line** window, you can type shell.help() to learn more of the tricks the **Command Line** window supports.

Data Logger

The Data Logger window gives a strip-chart view of a set of values plotted over time. It is very simple for scripts to add completely new categories of data (just use a unique name, and you've created a new strip).

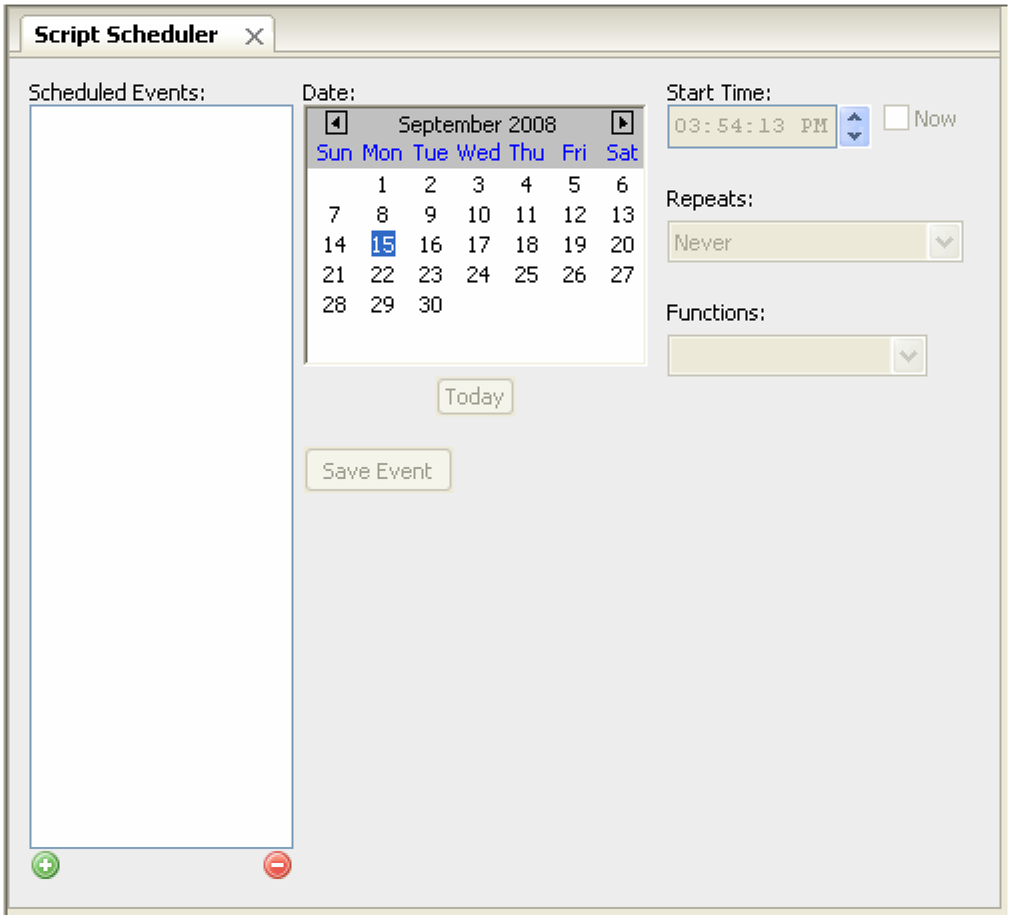
Scaling

The *vertical axis* is fixed at 100 units. Since a heterogeneous collection of data types may occupy the same plot, generic units are used. However, the *logData()* function accepts a scaling factor so that each value can map its full-scale range onto the vertical axis. The *horizontal axis* is a continuous timeline, with automatic scaling. You can plot multiple values, from the same or multiple nodes.



Script Scheduler

This button brings up the **Script Scheduler** window, which provides the ability to manage the scheduling of events (handler subroutines) from the current Portal script.



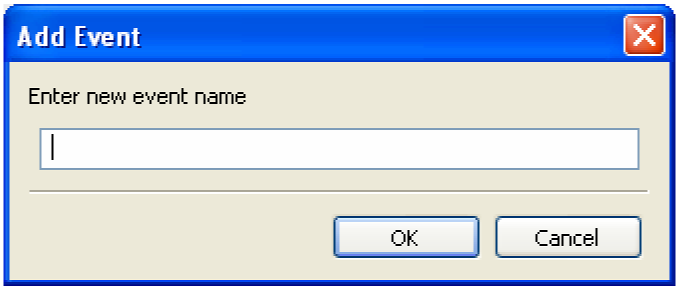
Normally events in Portal are invoked either by the user (by clicking on function names within the **Node Info** pane), or by remote SNAP nodes (via RPC). The **Script Scheduler** provides a third mechanism by which script functions can be invoked.

Note that you must have a Portal script loaded in order to schedule any events (the “event handlers” are functions already defined by your Portal script).

Note also that Portal has to actually be running in order for the scheduled event to be run. It does no good to schedule an event to occur at midnight, and then shut Portal down (or turn your PC off).

The and buttons at the bottom of the event list are used to add new events and delete existing ones.

If you click on the add button, you will be prompted to provide a name for the event.



Enter a unique event name in the dialog box, and click on OK. An event with the requested name will be *created*, but you still have to *configure* it.

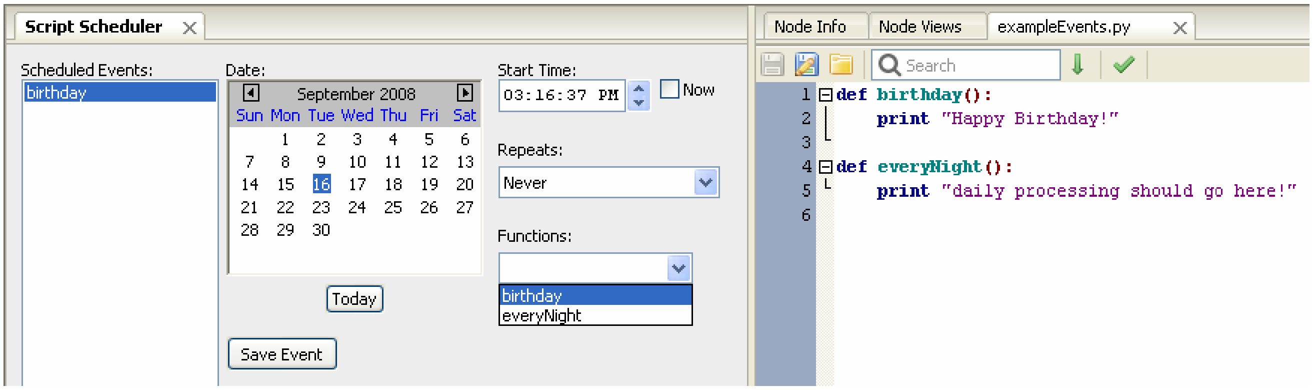
Click on an event in the list to select it, and then configure the event's *start date*, *start time*, and *repeatability*.

You choose the event's *start date* using the calendar control near the top of the pane. There is a **Today** button that is a shortcut to scrolling back to the current day (if you have changed it).

You choose the *start time* using the clock control to the right of the calendar control. There is a **Now** shortcut button, but since time marches on you will have to make some manual adjustments (Portal will not allow you to schedule an event in the past).

The **Repeats** control lets you choose if the event should only occur once (Repeats = Never), or if it should repeat every minute, every hour, or every day. You can also choose the special case of "On Load", which means the event will occur when Portal next loads a configuration containing that event (for example, at Portal startup).

After you have specified *when* you want the event to occur (and any optional "repeats"), you then must specify *what* you actually want to happen.



The **Functions:** drop-down selector lets you choose any of the functions defined in the currently active Portal script.

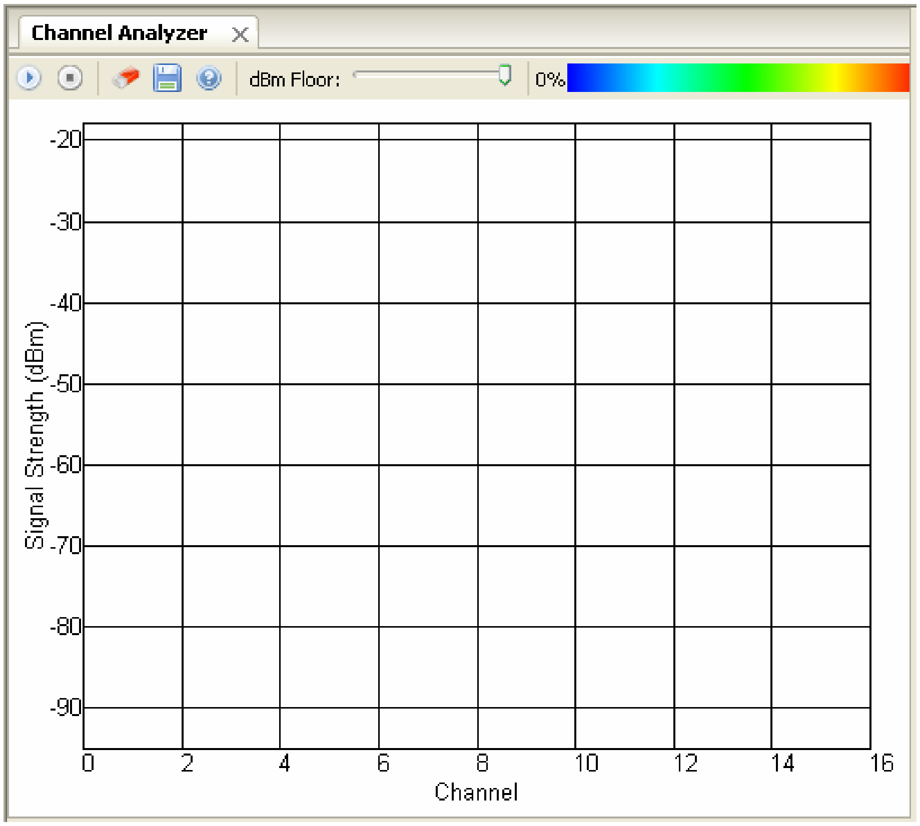
> This means you must load the correct Portal script *first*, before you can define events that use that script.

In the screenshot above, both the **Script Scheduler** pane and a **Script Editor** pane are shown. You can see the correlation between the **Functions:** field and the script source code.

When the event has been configured like you want, be sure to press the **Save Event** button.

Channel Analyzer

Clicking this button will open the **Channel Analyzer** pane within Portal.



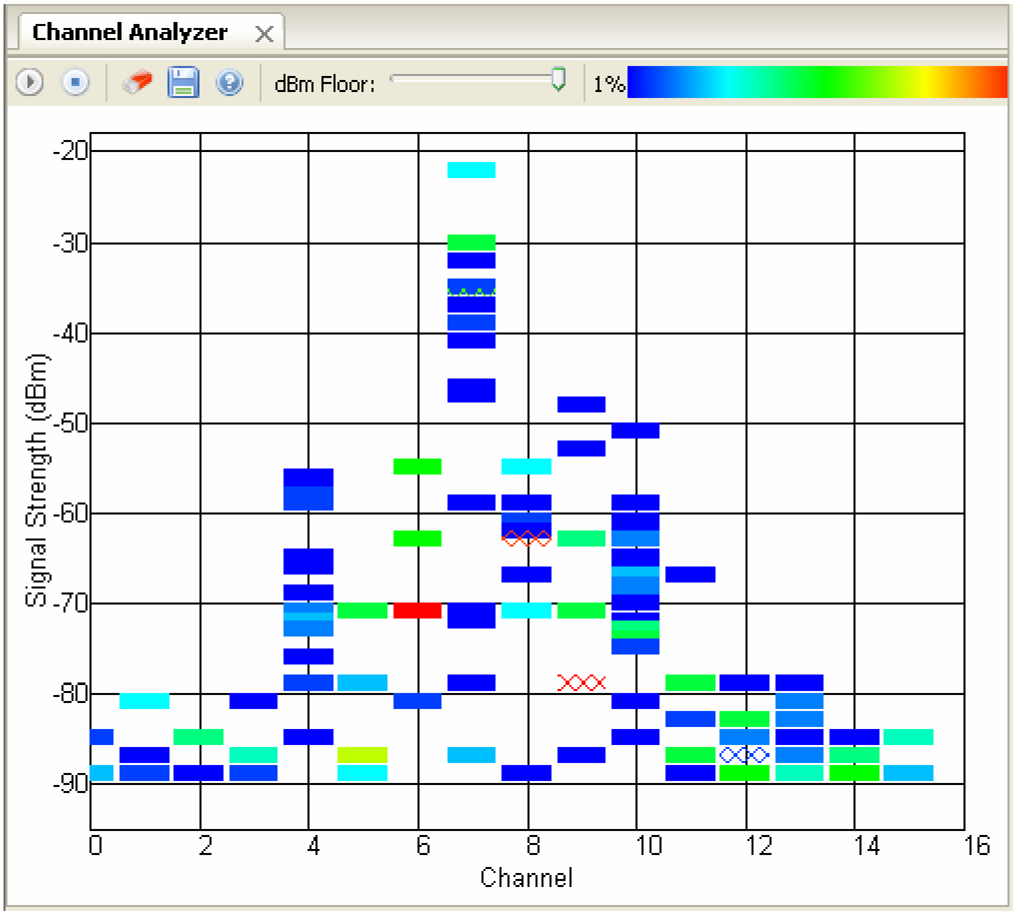
Performing a "channel analysis" (energy detection scan) consumes significant resources on your "bridge" node, so the function is only performed on demand.

Like many panes, the **Channel Analyzer** pane has its own mini-toolbar.

The **Start** button begins continuous channel scanning.
Once started, the **Stop** button can be used to stop it.
The **Clear Values** button can be used to erase any existing data and start a fresh plot.
The **Save Graph** button can be used to save the currently graphed data.
The **Channel Help** button brings up a list of channels, from weakest signal seen (most clear channel) to strongest signal seen (most crowded channel). This can help you choose a channel to put your nodes on.

A **dBm Floor** slider lets you choose a cutoff value for the graphed data. This lets you ignore low-level signals and focus on stronger ones.

Here is a screenshot taken from a system while scanning was actually in progress. Note that you may not have as much active traffic as in the example shown!



The colored bars in the chart provide three pieces of information simultaneously:

1) The horizontal position of each bar tells you the *channel* the signal was seen on
2) The vertical position tells you the signal strength seen on that channel
3) The color of each bar tells you the number of times a signal of that level has been seen (in % form). A color legend near the top of the pane shows you the scaling.

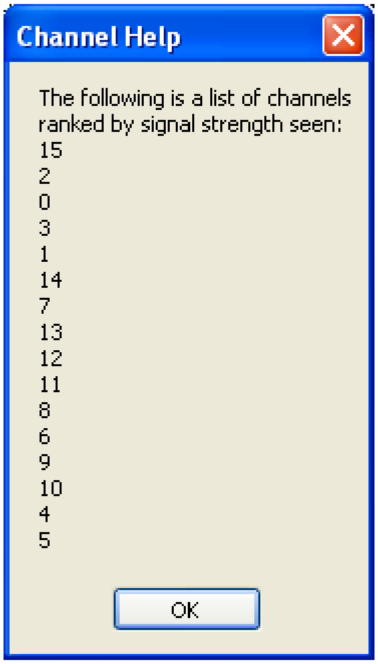
In the example above, you can see that the *strongest* signals have been detected on channel 7 (around -22 dBm), but that the *most frequently seen* signal is on channel 6 (at around -70 dBm).

Note that the **Channel Analyzer** takes "live" readings, and can only detect nodes that are actually *powered on*, *awake*, and *communicating* at the time of the scan.

You can restart your graph at any time with the **Clear Values** button, and you can save as many graphs as you want using the **Save Graph** button.

Be sure to use the **Stop** button when you are done. This will give your "bridge" node more time to handle other network traffic.

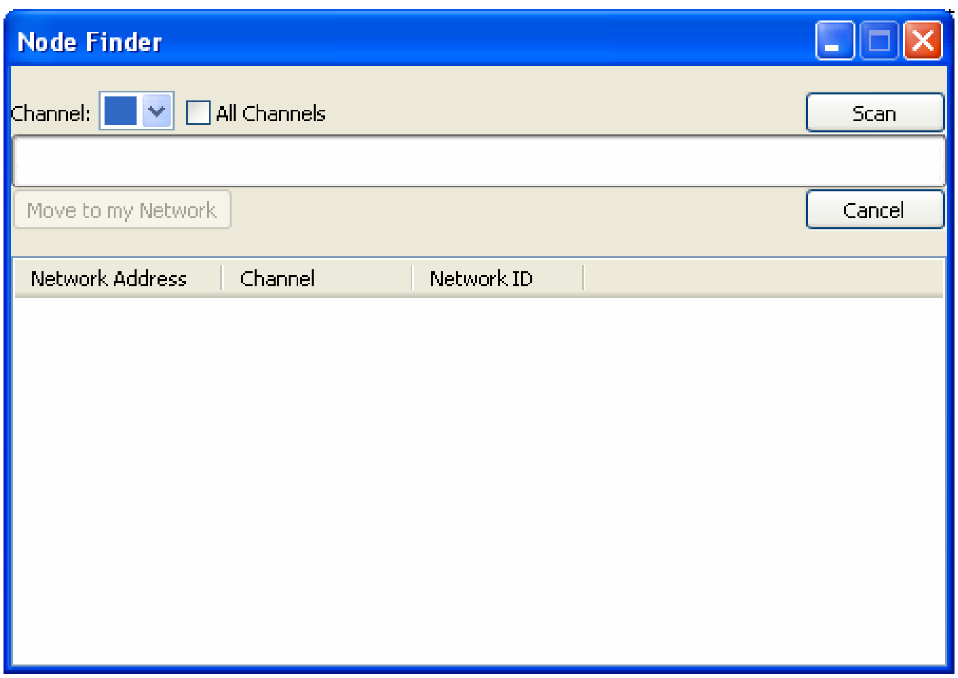
Clicking on **Channel Help** would bring up a dialog similar to the following:



As you would expect from the example chart, channel 15 is the best choice for newly deployed nodes (that channel is relatively quiet right now), followed by channels 2, 0, and 3.

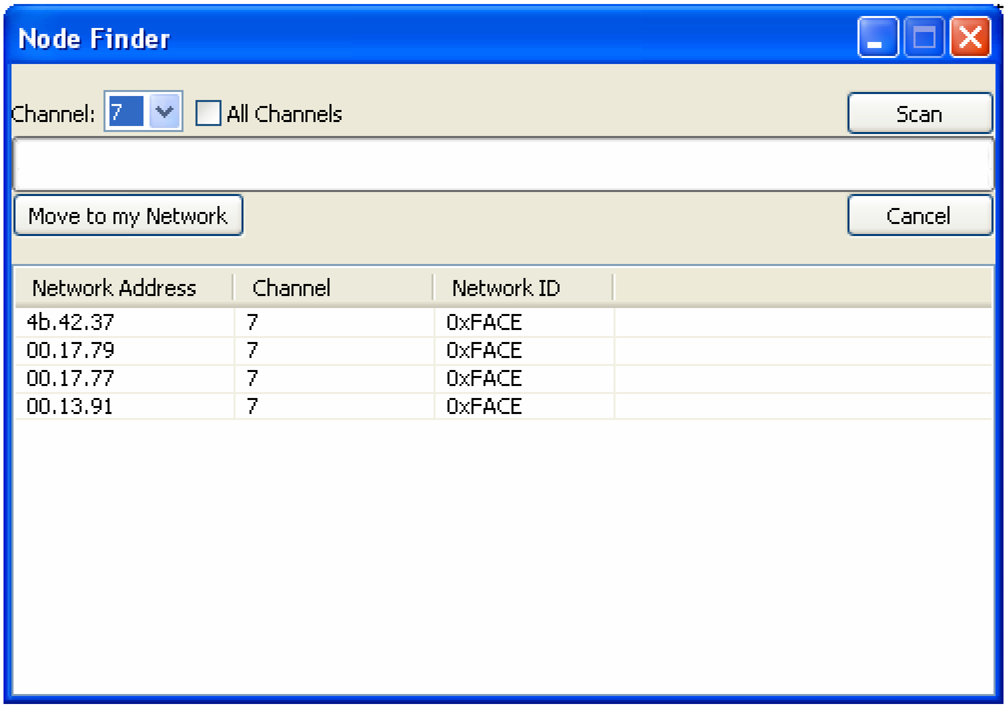
Find Nodes

Clicking on this button will bring up the following interactive dialog:



First choose a specific channel to scan, or click on **All Channels**. Next click the **Scan** button.

Portal will switch the “bridge” node to a special “wildcard” Network ID value that all nodes will respond to. Portal will then do broadcast pings on the specified channel (or all channels) and build up a list of all SNAP nodes that respond.



Note that this is an active scan, and Portal can only find nodes that are *powered on*, and *awake*.

In the example shown here, four nodes were found on Channel 7, Network ID 0xFACE.

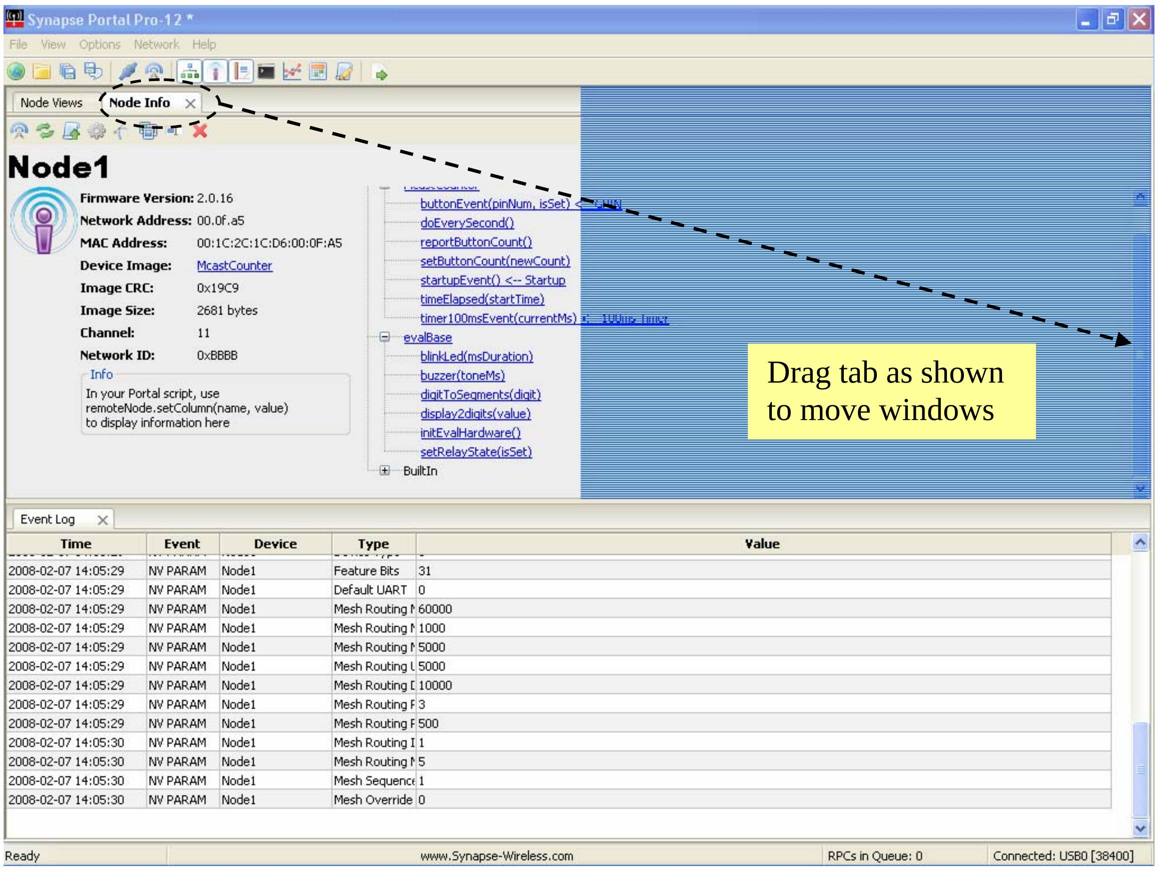
Because the broadcast ping process uses (unacknowledged) broadcast messages, some nodes may not respond. You may have to hit the **Scan** button more than once to find the node you are looking for.

If any of these nodes were *supposed* to be on the same channel and network ID that Portal’s bridge node is usually on, then they could be highlighted within the list, and the **Move to my Network** button clicked. Portal would then command the node to change channel and/or network ID as needed.

Press the **Cancel** button to close this dialog and resume normal Portal operations.

Rearranging Windows

The tabbed windows in Portal can be dragged and repositioned on the screen. To do this, press and hold the left mouse button while the cursor is positioned over the tab label you want to move. While holding the button down, drag the tab until you see a light blue “shadow” indicating a possible new position for the window. When you’ve found a suitable new position, just release the mouse button and the move will be complete.



Resizing

Windows may be resized by clicking and dragging the horizontal and vertical borders separating them.

15. Built-in Editor

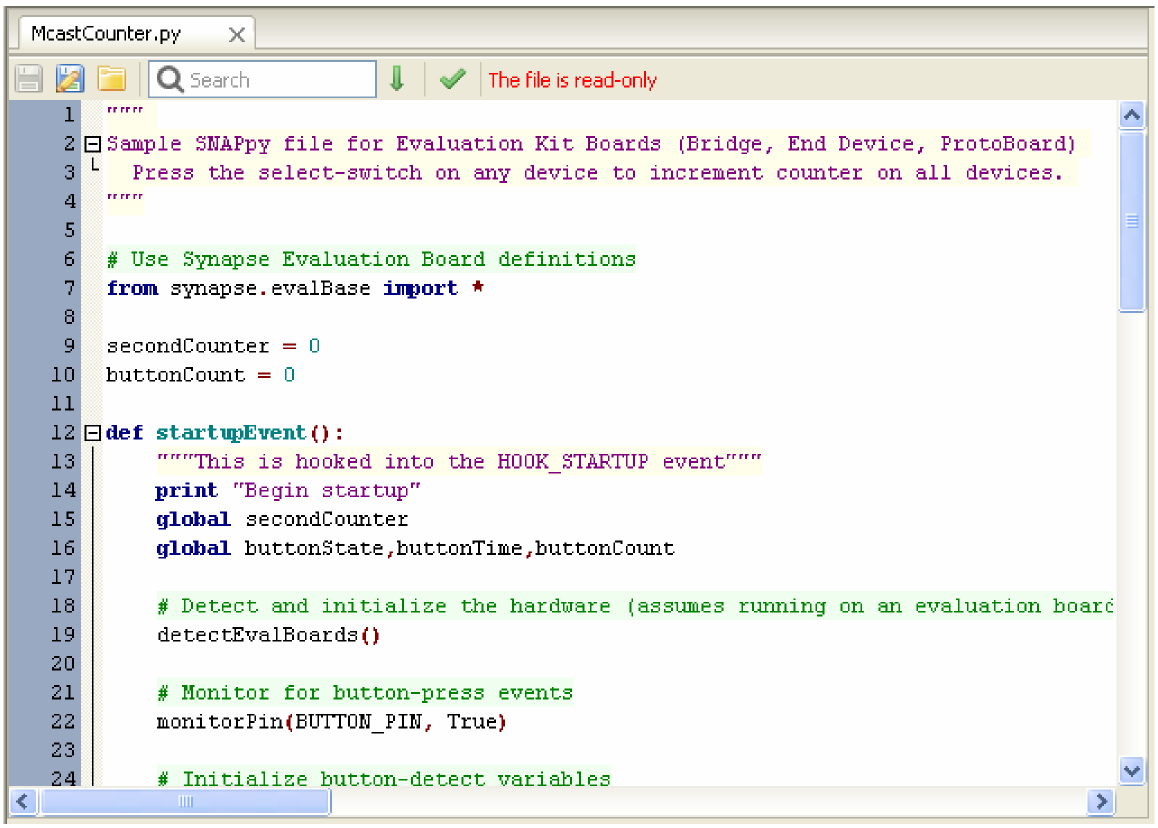
Portal includes a built-in code editor, making it an all-in-one solution.

> Note – if you already have a favorite editor, you can use it instead.

There are several ways to open an editor pane, here are a few:

- Click on a script name from the **Node Info** pane
- Use the **Open File** button on the main toolbar
- Use the **New Script** button on the main toolbar

Regardless of how you opened it, all the edit windows work the same.



A mini-toolbar provides buttons to **Save**, **Save As**, and **Open File.**

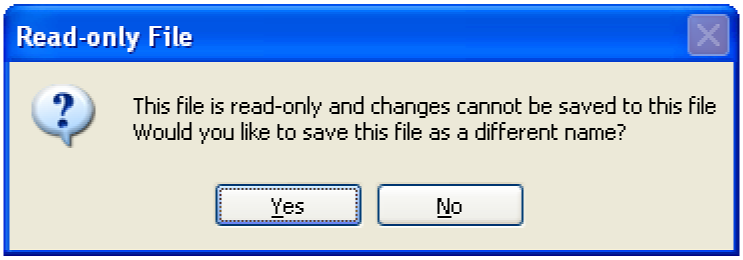
Next is a search window (CTRL-F is a keyboard shortcut for this), and a **Find Next** button.

The **Test SNAPpy Script** button lets you validate SNAPpy scripts (only) before you try to upload them into a node.

If you have opened a read-only file, an error message on the mini-toolbar will tell you so.

You can do a **Save As** to create a separate writable copy. This lets you start with an existing demo script, and make your own custom variation.

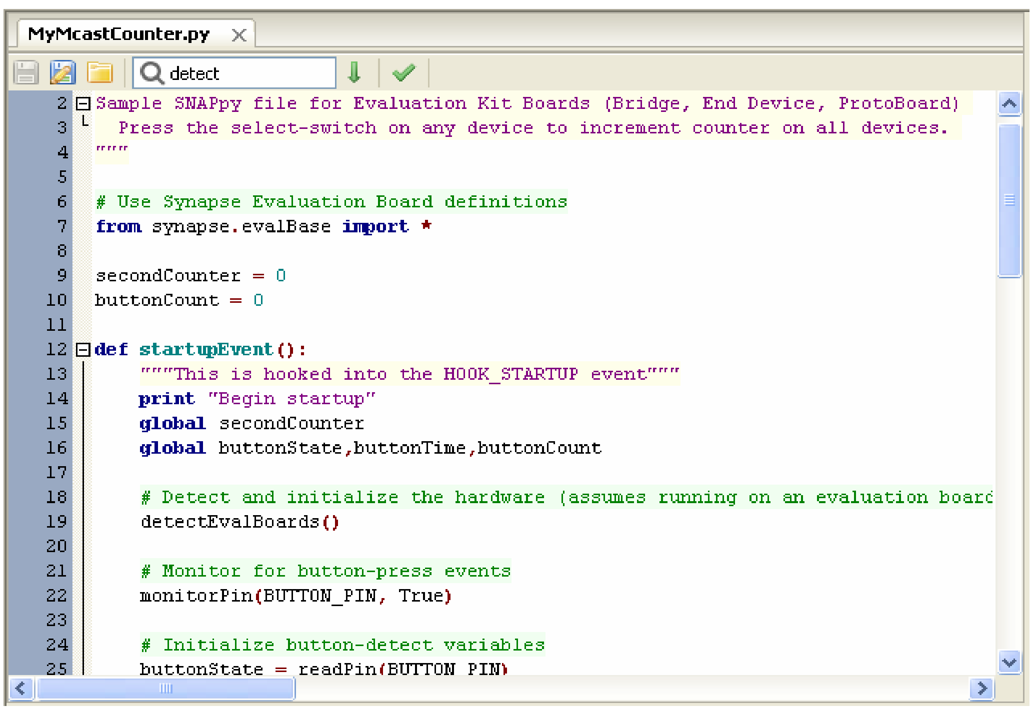
If you *try* to type characters into the edit window of a read-only file, Portal volunteers to save the file to a writable copy for you.



If you did not mean to be editing the read-only file, just click on No.

If you *do* want to edit a copy of the original read-only file, click on Yes.

The usual "file chooser" dialog box will allow you to choose the new file name. The edit window will automatically switch to editing the newly created file.



Be sure to **Save** your edits when you are done. Your new script can be uploaded into one or more SNAP nodes using the **Upload Snappy Image** button in the **Node Info** window.

16. Firmware Updates

The Firmware Version is shown in the **Node Info** pane for each SNAP node in your network. Upgrading your devices to a newer version of SNAP is easy with Portal.

> Upgrades use UART1 of the RF Engine. This means a connection to the second serial port (usually **RS-232**) of the Device being upgraded is required. Note that the new SNAPstick carrier does not support re-programming. You must move the RFE to some other board (like an SN171 Proto Board) in order to upgrade that RF Engine's firmware.

Obtaining Firmware

Each new release of Portal contains the most current version of the SNAP firmware *at the time of that Portal release*. Intermediate "firmware only" updates may also be available on the *Synapse Support Web Site*.

http://forums.synapse-wireless.com/

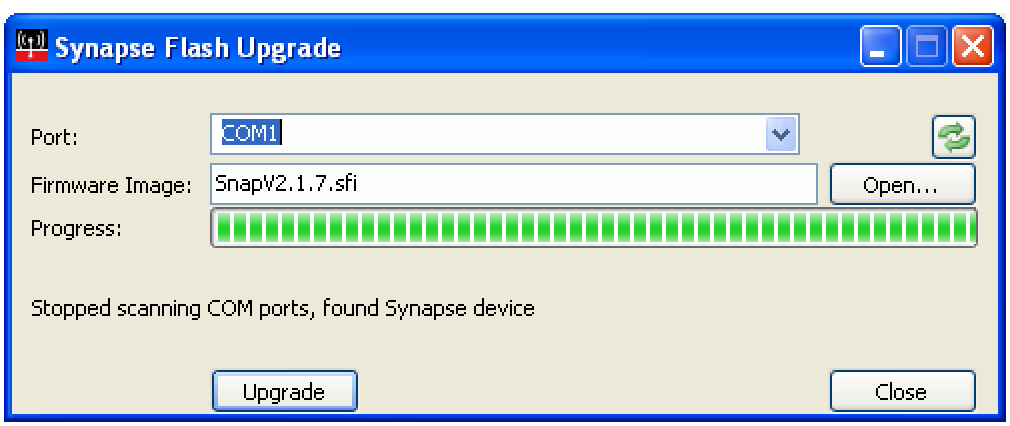
Look in the **Latest Releases** thread on the forum, under the **Software Releases** topic.

Note: Unlike in version 1 of SNAP, there is **not** separate firmware for what used to be called the Coordinator (SCO) and End Devices (EDs). Now a single common firmware image is used in all nodes.

Installing new Firmware

First make sure you have an **RS232** connection to the Device you are upgrading. This requires a connection to the DB9 connector on the Evaluation kit board, as *USB is not supported* for firmware upgrades.

From Portal's **Options** menu, select **Firmware Upgrade…** The following dialog box will be displayed.



Portal will scan your COM ports, and should find the first Synapse device connected to a serial port. If that is not the node you want to upgrade, you can hit the **Re-scan serial ports** button to automatically search for the *next* serial port with a responding node on it.

If Portal does not automatically find your SNAP node, you can manually select the correct COM port. If you have more than one node connected via RS-232 ports, you may also manually select the correct one instead of repeatedly pressing the button.

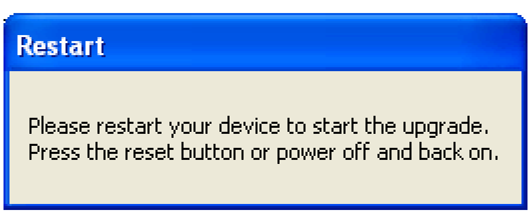
Select the Firmware Image to be used for the upgrade. Note that starting with version 2.1, there are now **four types** of firmware images to choose from:

> Firmware images with “debug” in the title have extra error checks to help debug user scripts and configurations. These extra diagnostic checks come at the expense of a slight decrease in speed and SNAPpy image space.
>
> Firmware images without “debug” in the title do not have these extra error checks, which allow them to run faster, and have more room for SNAPpy images.
>
> Firmware images with AES128 in their name have built-in support for AES-128 over-the-air encryption. These images are not included with Portal, but can be ordered separately from Synapse (there is an additional charge for AES-128 support).
>
> Firmware images without AES in the title do not support AES-128 encryption.

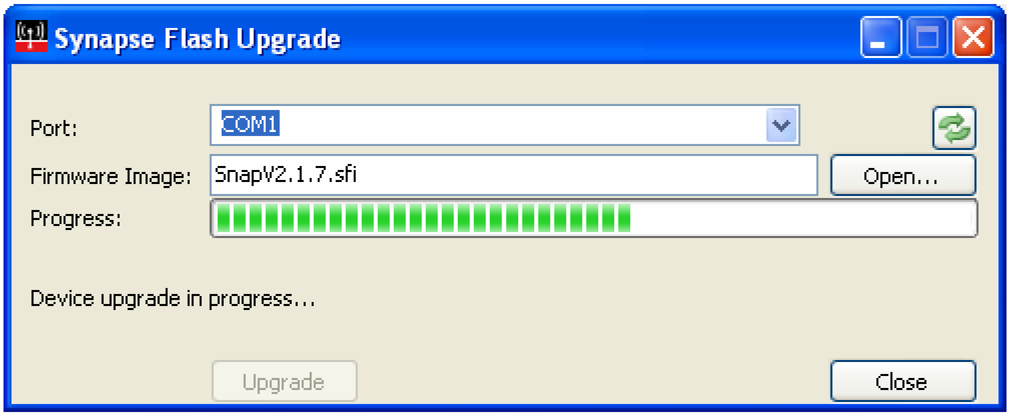
The firmware image names also indicate the version of that firmware. For example, 2.1.5 is newer firmware than 2.0.32, and 2.1.8 is newer than 2.1.7.

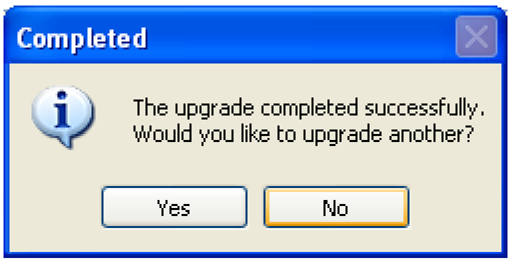
After choosing the correct firmware image to load, press the Upgrade button to begin.

Follow the instructions given in the dialog, which may have you restart (power-cycle or reset) your device to complete the process.



New firmware will be sent to the SNAP node over the serial connection.





Choose Yes to download the same image into another SNAP node, or No to return to Portal.

Troubleshooting

There is a possibility of interruption (power, serial connection, etc.) in the midst of the upgrade process. This may leave the SNAP node in a state where the SNAP application firmware is unusable. However, **upgrade is still possible**, since the SNAP boot-loader firmware is protected in a "locked" region of flash. Simply restart the upgrade process – this time you'll need to *manually select the appropriate COM port* for RS232 communication, since Portal won't be able to detect a running RF Engine on the serial port.

17. License Activation

The default install of Portal Software is licensed as Portal-12. This limits your SNAP Network to 12 nodes, but provides a base level of product features suitable for evaluation and simple, small network configuration.

Versions of Portal included in some of the smaller "Evaluation Kits" may be licensed for smaller numbers of nodes.

Obtaining a License

Portal product levels beyond 12 nodes require the purchase and installation of a License. Licenses may be purchased online at http://www.synapse-wireless.com/, or you may contact a Synapse Sales representative at 1-877-982-7888.

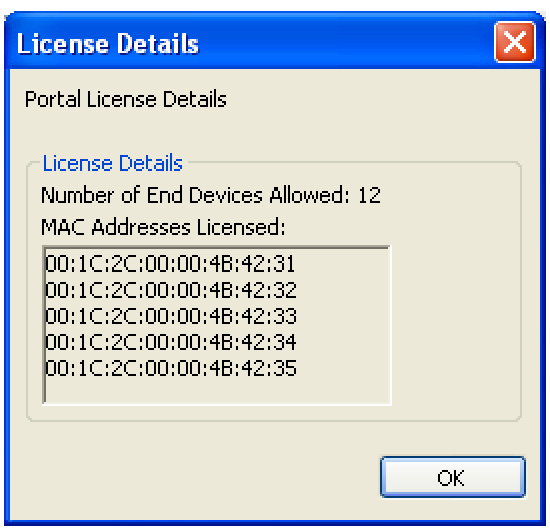
Installing the License

Your Portal License is delivered as a single file, which you can simply copy into the directory on your hard drive where Portal was installed. By default, this is:
`C:\Program Files\Portal`
(Your install directory may differ, if you changed the location during install.)

The License file should be renamed to: **`PortalLicense.dat`**

After installing a new license, Portal must be *restarted* for the new features to take effect. Once restarted, you should see the new Portal product level reported in the title-bar of the Portal application window.

You can also use **Help** -> **License Details…** to see what your current license settings are.



18. Notes for Users Familiar with SNAP 1.x

Fundamental differences between SNAP version 1.x and SNAP version 2.x sometime confuse users of the older product line. (Users who have never even seen a SNAP 1 node can ignore this section).

The seven-segment display is no longer just Link Quality

In the original SNAP products, the seven-segment display was only used to show Link Quality. In SNAP 2.x, users have complete control over all 14 segments (2 character positions times seven segments each).

Nothing is put on the seven-segment displays *by default*. You **must** use a SNAPpy script to write data to these displays.

To reiterate: *a blank seven-segment display does not mean your unit is dead!*

There are no longer any AT Commands

SNAP 1.x had no Packet Serial mode, and did not support Remote Procedure Calls (RPC).

SNAP 2.x replaces the AT command interface of SNAP 1.x with a more robust Packet Serial interface, and an even more powerful RPC capability.

There are no longer Coordinators and End Devices

One node still has to act as a “bridge” to connect Portal to the rest of the network, but there is no longer a dedicated Coordinator. Instead, *any* node with an available serial interface can act as a bridge, and **all** nodes can perform Mesh Routing, etc.

Snappy Cheat Sheet

Snappy Language

All statements must end in a newline:

```
print "I am a statement"
```

Blocks are indicated by one or more spaces, following a statement that ends with a colon (:)

```
if name == "Snappy":
     print "Welcome!"
```

Comments start with a #:

print "Hello" # I'm a comment

Control Flow

Use **if** to decide what code block to execute:

```
x = 1
if x == 1:
   print "Found number 1"
```

The **elif** and **else** reserved words are optional:

```
x = 1
if x == 1:
    print "Found number 1"
elif x == 2:
    print "Found number 2"
else:
    print "Did not find 1 or 2"
```

Use **while** to execute code as long as a condition is met:

```
x = 0
while x < 10:
    print x
    x = x + 1
```

Conditionals

==	Equals
!=	Not equals
>	Greater than
<	Less than
>=	Greater than or equals
<=	Less than or equals
and	Both must be true
or	Either can be true
not	Boolean inversion

Identifiers

Identifiers are case sensitive names used to describe variables and functions. They must start with a non-numeric character and only contain alphanumeric and underscore (_) characters.

The **global** reserved word declares identifiers as globals in the current code block:

```
global buttonState, buttonCount
```

Reserved words:

```
and assert break class continue
def del elif else except exec
finally for from global if
import in is lambda not or pass
print raise return try while
```

Functions

Functions are defined using the **def** reserved word:

```
def mySnappyFunc():
     print "Hi Snappy!"
```

Required function parameters are defined by adding identifiers in the parentheses:

```
def addrFunc(param1, param2):
     result = param1 + param2
     print result
```

Importing

Snappy modules can import other modules with **import**

```
from evalBase import *
```

Arithmetic

+	Addition operator
-	Subtraction operator
*****	Multiplication operator
/	Division operator
%	Modulo operator

Data Types

str	String
int	Integer
bool	Boolean
function	Function

RF Engine Pin Assignments

Pin No.	Name	Direction	Description
1	GND	-	Power Supply
2	GPIO0_TPM1CH2	Bidirectional	GPI/O, or Timer1 Channel 2 (ex. PWM out)
3	GPIO1_KBI0	Bidirectional	GPI/O, Keyboard In
4	GPIO2_KBI1	Bidirectional	GPI/O, Keyboard In
5	GPIO3_RX_UART0	Input	UART0 Data In
6	GPIO4_TX_UART0	Output	UART0 Data Out
7	GPIO5_KBI4_CTS0	Bidirectional	GPI/O, Keyboard In, or UART0 CTS
8	GPIO6_KBI5_RTS0	Bidirectional	GPI/O, Keyboard In, or UART0 RTS
9	GPIO7_RX_UART1	Input	RS232*/UART1 Data In
10	GPIO8_TX_UART1	Output	RS232*/UART1 Data Out
11	GPIO9_KBI6_CTS1	Bidirectional	GPI/O, Keyboard In, or RS232*/UART1 CTS
12	GPIO10_KBI7_RTS1	Bidirectional	GPI/O, Keyboard In, or RS232*/UART1 RTS
13	GPIO11_AD7	Bidirectional	GPI/O, Analog In, CBUS CDATA, or SPI MOSI (Master Out Slave In)
14	GPIO12_AD6	Bidirectional	GPI/O, Analog In, CBUS CLK, or SPI CLK
15	GPIO13_AD5	Bidirectional	GPI/O, Analog In, CBUS RDATA, or SPI MISO (Master In Slave Out)
16	GPIO14_AD4	Bidirectional	GPI/O, or Analog In
17	GPIO15_AD3	Bidirectional	GPI/O, or Analog In
18	GPIO16_AD2	Bidirectional	GPI/O, or Analog In
19	GPIO17_AD1	Bidirectional	GPI/O, Analog In, or I2C SDA
20	GPIO18_AD0	Bidirectional	GPI/O, Analog In, or I2C SCL
21	VCC	-	Power Supply
22	PTG0/BKDG	Bidirectional	Background Debug Communications
23	RESET*	Input	Module Reset, Active Low
24	GND	-	Power Supply